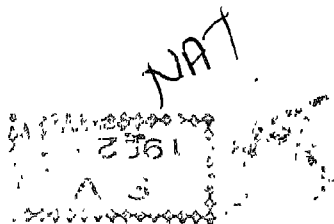
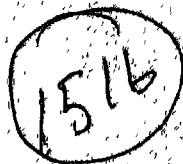


UNITS ON ELECTRICITY



INSTRUCTIONAL MATERIALS SERIES • 2 •



NATIONAL COUNCIL OF
EDUCATIONAL RESEARCH AND TRAINING

INSTRUCTIONAL MATERIAL SERIES-2

UNITS ON ELECTRICITY



NATIONAL COUNCIL OF EDUCATIONAL
RESEARCH AND TRAINING

1966

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FOREWORD

In the last decade, Science and its concomitants have invaded India. Electricity is not now limited to big or small towns ; it has reached the remote village. The wonders of electricity have been made manifest to the rich man in his refrigerator to the poor farmer in his pumping set. In a sense this age through which we are passing could be called the Age of Electricity.

How much do we understand of how electricity works ? "Units on Electricity" seeks to explain this. It is intended for the Reader who wishes to know something about the principles of electricity and depends upon himself to obtain and make use in practice of his information. The approach used in the book is non-mathematical. Only the simplest equations related to the fundamental laws of electricity are employed. The content has been so organised as to tempt the learner to put his knowledge into practice and so that he may gradually develop from indigenous materials, projects like house wiring, a hot plate, an electric motor and a crystal radio.

These are inexpensive and interesting projects that stimulate creativity. They serve as a point of departure for other activities that can be undertaken in the Indian home.

The book is also useful as instructional material for school students. Industrial crafts, that are being introduced into our school system, include wood work, metal work and electricity. This small book has a direct bearing on these craft activities.

Dr. Arthur W. Earl, the author, was in India as a USAID Consultant with the Ohio State University Team. Out of his experience with students of Mayo College, Ajmer, this book was born. I hope that it will be useful to a wide range of people, since it has the advantage of being written persuasively and against the background of Indian conditions and materials.

New Delhi,
June 10, 1966

L.S. Chandrakant
Joint Director,
National Council of Educational
Research & Training

ACKNOWLEDGEMENTS

The development of instructional material that interprets industry and exemplifies the best educational practices for technology must draw upon the knowledge, service and cooperation of many people and organizations. The author is profoundly appreciative of the outstanding contributions made by so many people. They have provided the authoritative touch so essential to the successful development of this instructional material in electricity.

The technical aspects of electricity demand that information be obtained from organizations capable of providing the correct, authoritative information. The electrical engineers at Bhakra Dam were most cooperative in providing the technical information pertaining to the generation and transmission of electricity. The Indian engineers and electricians, employed at U S A.I.D. Maintenance Unit, New Delhi, were extremely helpful in providing general electrical information. To Mr D.N. Sharma, I express appreciation for the full cooperation of his department. I also wish to express my sincere thanks to the Communications Media Branch, U S A.I.D., for their cooperation and assistance. Mr. J.P. Gupta was kind enough to permit me to use his electrical workshop. Mr. N. Nath prepared the excellent photographs of the working models. The art work for the electric motor (experimental and testing stages) was capably prepared by Mr. Kailash Chand.

Personal thanks are extended to Mr. Dan Mal Mathur, Vice Principal, Mayo College, Ajmer, for the privilege of conducting the first 9th year Technology Workshop in electricity at Mayo College. The instructional materials in electricity were received very enthusiastically by the students and I personally found their response and the entire experience very gratifying.

The technology staffs at the Regional College of Education in Ajmer, Bhubaneswar and Mysore were very helpful in reviewing the entire approach used in the development of the instructional materials in electricity. Personal thanks are extended to Mr. S.G. Mathur, Reader in Industrial Crafts, for arranging and assisting in the successful testing of the instructional materials in electricity at Mayo College.

Three American U.S. A.I.D. technicians, J. Marshall Hanna, Willis E. Ray, and Fred A. Olsen assisted in the conception and compilation of this publication.

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Mr. D.B. Chopra of The Ohio State University central office staff, New Delhi, made many outstanding contributions during the development of the instructional material in electricity. I extend my sincere thanks to Mr. Chopra for his conscientious effort and the excellence of his work.

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Arthur W. Earl
Consultant in
Teacher Education-Technical Education
Under U.S A.I.D. Programme,
The Ohio State University

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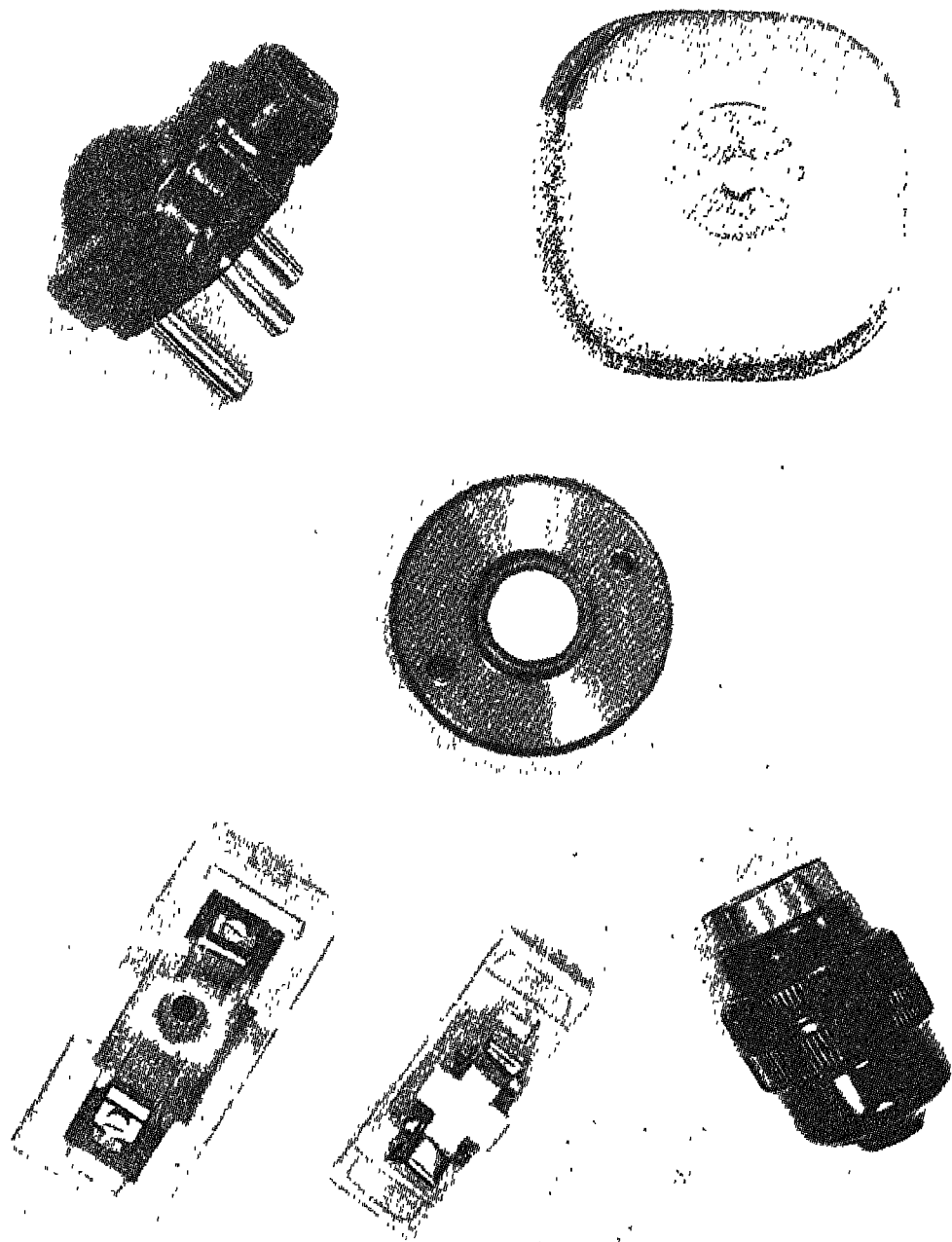
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UNITS ON ELECTRICITY

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ELECTRICITY

Typical Electrical Accessories for House Wiring Installations

Unit 1

HOUSE WIRING

1. GENERATION AND TRANSMISSION OF ELECTRICITY

ELECTRICITY is rapidly taking a prominent part in the everyday lives of people throughout the world, especially in the home. Imagine the convenience and pleasures of living that one can look forward to, when every home throughout India can be supplied with sufficient electricity. Each home, no matter how large or small, would be supplied with *light* and *power* for cooking and heating. The entire country would be electrified, from the largest city to the smallest village.

1.1 Electric Power Plants

Three main types of electric power plants would make this electric energy available for use.

- (1) *The hydroelectric plant* which harnesses the force of flowing water to mechanically operate the generators that produce the electric energy.
- (2) *The thermal electric plant* which burns coal, oil or gas to make steam. The steam energy mechanically operates the generators that produce the electric energy.
- (3) *The atomic electric plant* where atomic energy is converted into heat energy that is used to produce steam. The steam energy mechanically operates the generators that produce the electric energy.

The basic difference between these three types of electric plants is the power used to turn the generators. However, the generators and the electric energy created by each of the three types of power plants are basically the same.

The hydroelectric power plant, which serves many other purposes besides the generation of electricity, may be the most useful for India. The river water that turns the generators and produces the electricity must be stored behind dams. The stored water can be controlled to turn the generators at the correct speed. Also the stored water which is collected during the monsoon season will always be available for use during the dry, hot season. Therefore, the generators can be operated all year around from the rivers' harnessed waters.

India has many large rivers that carry the surplus flow of the monsoon rains to the sea every year. In its passage to the sea the flood water causes immense damage to the land and creates hardship on life. Most of the land lies at the mercy of the heavy rains. However, if the water were collected and stored behind dams with controlled distribution, then the destructive monsoons could be made to yield rich dividends throughout India.

- (1) The stored water could be used for the operation of hydroelectric plants that would supply electricity for homes and industry, and light villages and towns.
- (2) The stored water could be used for irrigation purposes all year around,

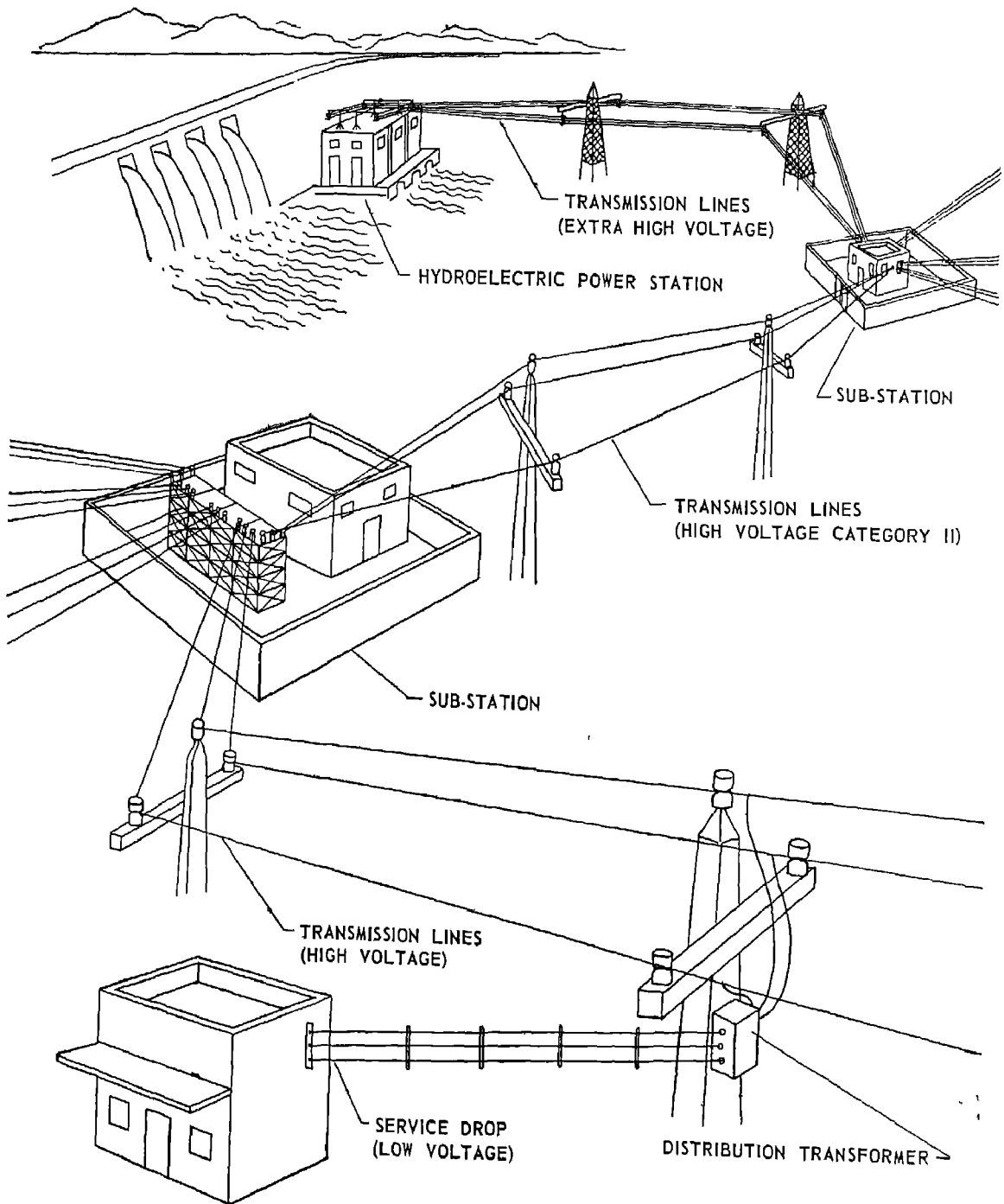


Fig. 1.2.A. Generation and Transmission of Electricity

- (3) An adequate supply of water to crops at the right time could more than double the average yield.
- (4) The same water could be used for transportation of people, raw materials, agricultural produce and industrial products.

If much of the water now running to waste could be harnessed and controlled, the benefits as just described, would change the face of almost all of India into a more prosperous land. Statistics show, from the dam systems already completed, that hundreds of miles of large and small canals are constantly fed with running water, that millions of acres of arid land have now been brought under cultivation, and that millions of kilowatts of electric power have been generated for Indian homes and industries.

1.2 Principles of Electric Generation and Transmission

The principle of the generation and transmission of electricity, illustrated pictorially in Fig. 1.2.A, shows the entire concept from the place where electricity is generated to its service entrance in the home.

The hydroelectric plant, which is capable of producing large amounts of electric energy, sends the extra high voltages produced across the country on transmission lines. Some transmission lines carry voltage as high as 66,000 or 220,000 volts. Sub-stations provide for the proper distribution of electricity, as it crosses the country, into lower voltages. Several sub-stations may be used to gradually step the voltage down to 33,000, 11,000, 6,600 and 3,300 volts. Each sub-station, because of this large amount of electricity, is capable of sending out lower voltages, on many more transmission lines, in all directions. When the voltage has reached the pole near your house it has probably been stepped down to 3,300 volts. A distribution transformer mounted on a pole near your house will step down the service wire voltage to 220 volts. This places the electricity, with proper safety precautions,

within what can be considered safe limits for use in the home.

1.3 Hydroelectric Generation

Hydro is a combining form meaning water. Therefore, the word *hydroelectric* means electricity produced by water power. *Generator* is a general term applied to machines by which mechanical energy is transformed into electrical energy.

When water power is used to turn a generator large quantities of rapid flowing water are required. This is accomplished by huge dams from which powerful forces of water can be directed into giant turbines. A *turbine* is like a huge water wheel built inside a casing or housing. The principle, as shown in Fig. 1.3.A, would be similar to directing a strong force of water over a Persian Water Wheel. As the water wheel revolves rapidly, a shaft connected directly to the generator turns the generator at high speed and produces the electricity. Generators are usually designed to produce approximately 13,000 volts.

The 13,000 volts produced by the generator is fed into a step-up transformer. The step-up transformer is capable of greatly increasing the voltage for transmission to any desired higher voltage such as 66,000 or 220,000 volts.

1.4 Transmission Towers

The style and number of towers used in the transmission of electricity varies. Transmission towers may be made of wood, metal or concrete. The style of tower selected depends upon the availability of materials, cost, strength, distance between towers and location. They may vary in shape from single poles, to 'H' frames, or to large towers of different shapes. They may be spaced from less than one hundred feet apart to approximately a thousand feet between towers. Varying factors such as the amount of voltage, location of the tower, shape of the terrain and height from the ground, will affect the distance between transmission towers.

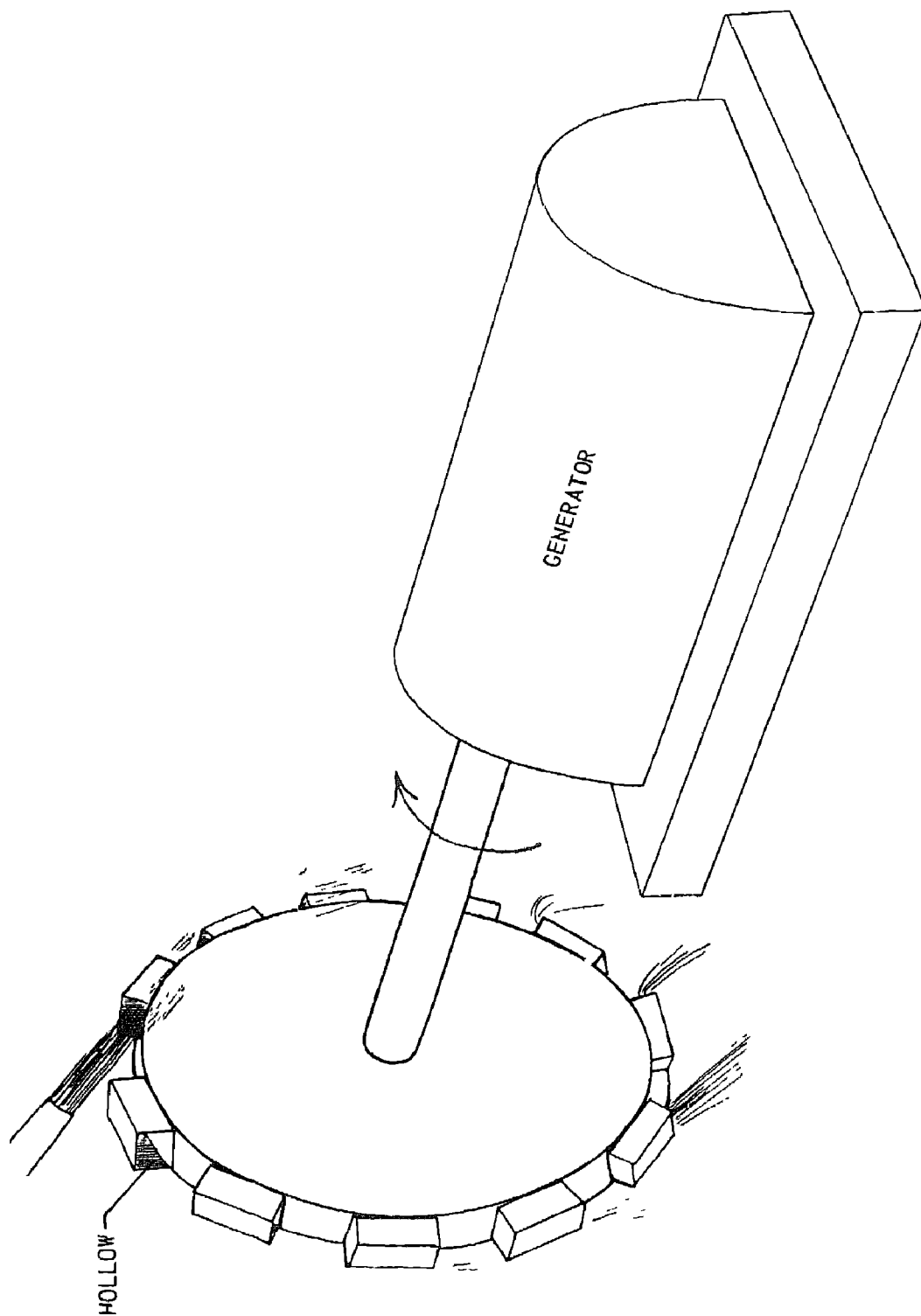


Fig. 1.3.A. Principle of Hydroelectric Generation

1.5 Transmission Lines

Transmission wires, or lines, conduct the electricity from the hydroelectric plant where it is generated to the place where it will be used. These lines must be capable of carrying excessively high voltages such as 66,000 or 220,000 volts. The transmission of excessively high voltages is necessary because of the large *voltage drop* (loss of power) over many miles of wire. Also, at the sub-stations where the electric power is distributed, there must be ample power available to divide up into many smaller units of electricity. The transmission lines for electricity might be compared to the canal system of irrigation. The large canals carry an ample supply of water which is fed into many smaller canals. The small canals feed into many more major irrigation ditches. The major irrigation ditches are fed into many more smaller irrigation ditches. In the process much water is lost in seepage, in the same way as electricity is lost (voltage drop) in the transmission lines. Actually the *transmission* of electricity, the same as water for irrigation, is a process of dividing up the major supply source into thousands of smaller equal supplies for distribution throughout the land.

Transmission lines are made of copper, aluminium or steel. Aluminium, because of its light weight, is usually used on long expanses between transmission towers. Transmission lines are either made up of several strands of wire or are hollow. The advantage of several strands of heavy wire is that the cable is flexible and can swing in the wind without breaking. The hollow transmission wire, like tubing, makes a stronger cable than a solid wire of the same weight.

It is necessary, because of the high voltage, to support and insulate the transmission wires from the tower arms by insulators. The *insulators* prevent the electricity from *shorting* between the wires, or the transmission poles. A short circuit is the accidental connection of two sides of a circuit, through which an abnormal flow of current can pass. Insulators are usually made of porcelain or glass. The quality and number of

insulators used depend upon the amount of voltage being carried in the wire, and the strength needed to support the wire.

High voltage transmission lines are spread out across the entire country in a vast system or network of wires called a *grid*. One might vision this vast network of wires as a giant sized spiderweb. These high voltage transmission lines are easy to distinguish because of the large transmission towers, heavy porcelain insulators and big wires. However, when the high voltage transmission lines reach the city and the voltage is distributed into a lower voltage on many more smaller transmission lines, it becomes more difficult to distinguish one wire from another. It may be assumed, however, in a housing colony that the three wires on top of a single transmission pole are 3,000 volts or more. Wires running parallel to each other along the side of a pole, mounted one above the other, are normally for house use and usually carry 220 volts. These are the wires that lead into the house, either above ground or below ground and are called the Service Drop.

2. ELECTRICITY ENTERS THE HOME

2.1 Service Drop

The above ground service drop, as shown in Fig. 2.1.A, is supported from above by a steel cable and usually contains two, three or four insulated service wires. The 220 volt wire, sometimes referred to as the *LIVE* or *HOT* wire, is the *positive wire*. If you touch this wire it will give you a shock. The *neutral wire*, sometimes referred to as the ground wire, negative wire or cold wire, is used to complete the electric circuit. If you touch this wire it will not give you a shock.

Certain types of protective devices for the transmission of electricity, as shown in Fig. 2.1.B, are required under the Indian Electricity Rules as a precaution for public safety.

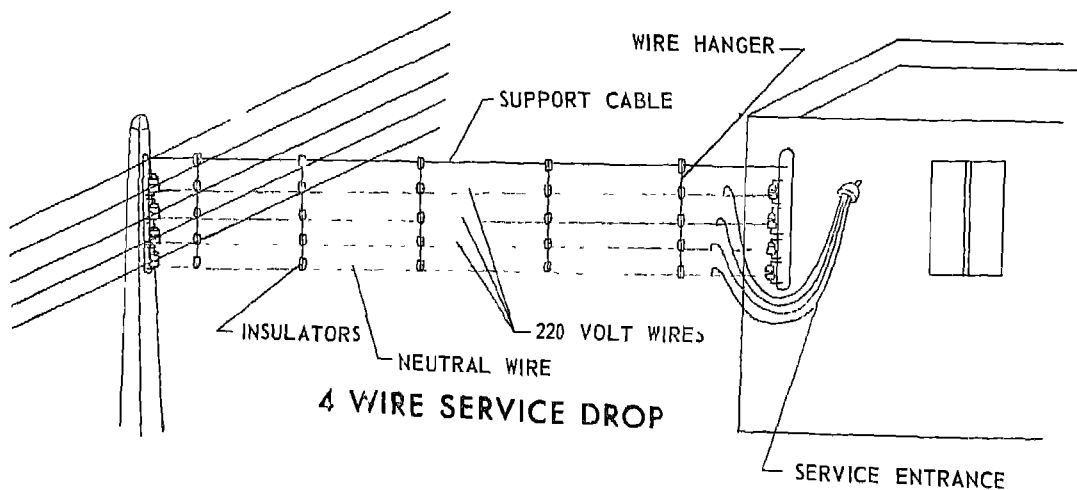
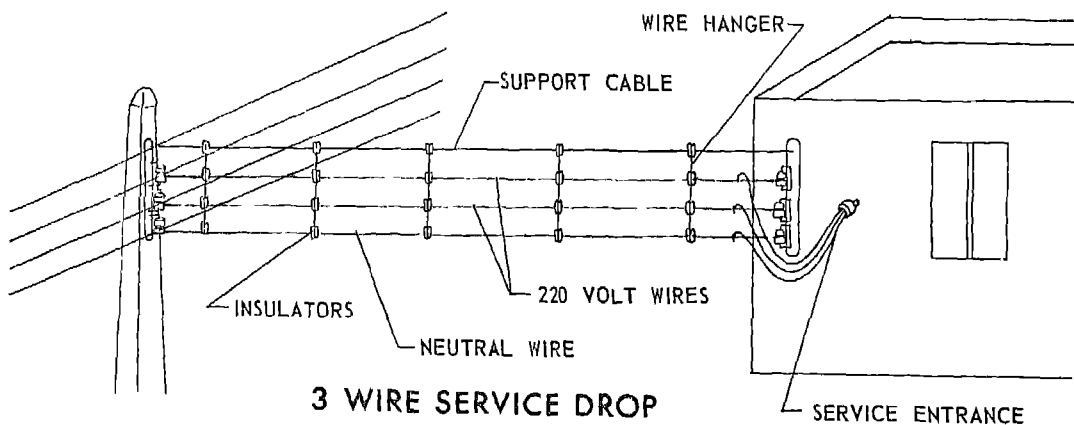
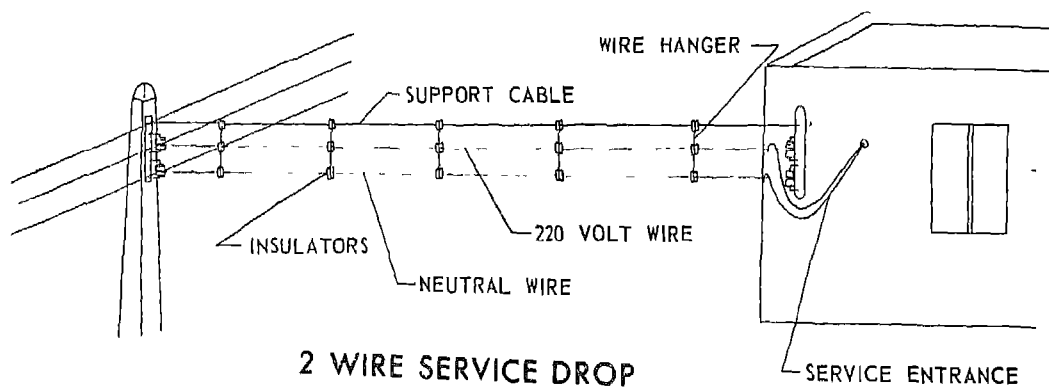


Fig. 2.1.A. Types of Service Drops

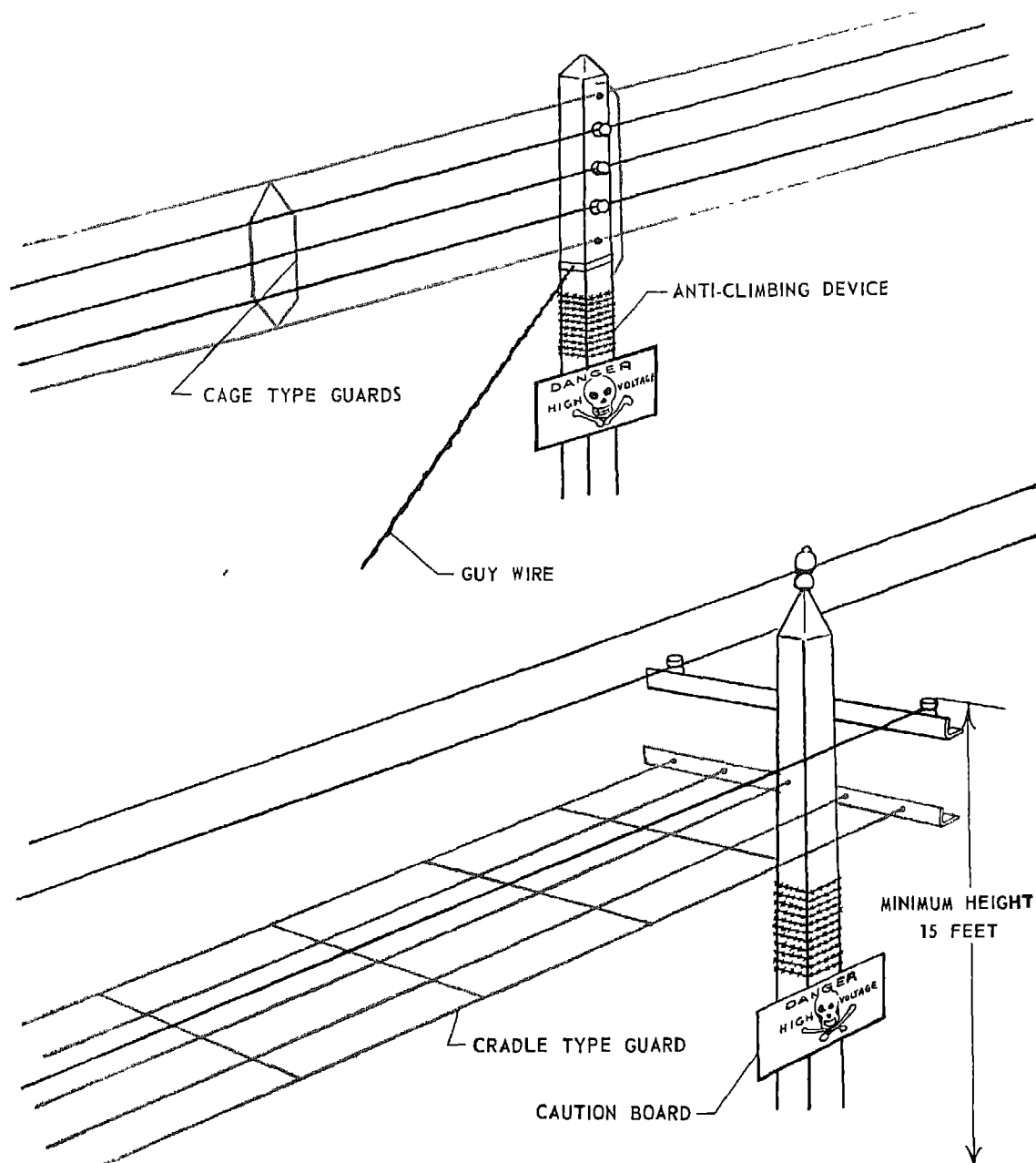


Fig. 2.1.B. Transmission Line Protective Devices

- (1) Any transmission line erected along any street shall be at a minimum height of 15 feet.
- (2) Caution boards or anti-climbing devices are to be installed wherever an electric line is considered to be vulnerable.
- (3) Guarding of electric lines along the road or across the road is to be provided if required by the electrical inspector.

2.2 Service Entrance

The service entrance consists of the service drop wires; the entrance head; the distribution panel on which are mounted the watt-hour meters, disconnect switches and fuse boxes; and the service ground connection.

The *entrance head*, as shown in Figure 2.2.A, is designed to permit the service drop wires to enter the house in a safe manner. It also prevents rain from entering the *conduit* (the pipe that contains the electrical wires) which would cause severe damage to the electrical system.

The *distribution panel* may be the open face type or the closed in box style. Most of the installations in the newer houses, because of the improved safety factor, are the enclosed box style. Two watt-hour meters are usually mounted on the distribution panel. One watt-hour meter is connected to the *light* circuit, the other to the *power* circuit. There are two meters because the electric companies charge two different rates for the use of electricity. The watt-hour meter that services the light circuit, which includes lights, ceiling fans and other general purpose outlet receptacles has a higher charge rate. The watt-hour meter that services the power circuit, which includes geysers, hot plates and other heavy duty outlet receptacles, has a lower charge rate.

The *watt-hour meter* is connected directly to the service drop lines. Therefore, the electric company assumes responsibility for the electricity up to the *input* side of the watt-hour meter. However, on the *output* or *load* side of the watt-hour meter, you pay for the electricity according to how much you use. The watt-hour meter measures

the electricity consumed in units of *Kilowatthours* (kwh). The watt-hour meter operates only when electricity is being consumed. It is like the odometer on a car which measures the mileage only when the car is in motion.

There is no difference between the electricity being used through the 'light' watt-hour meter or the 'power' watt-hour meter. Therefore, for purposes of description the operation of one watt-hour meter will be described. The term power, however, when used in this description will not refer to the power watt-hour meter, but will mean the measure of 'electric power' in units of kilowatt-hours. Electric power companies use this unit of measurement in determining the charge for the electric power they furnish. One *Kilowatthour* of power means a thousand watts of power have been consumed in one hour. The watt-hour meter is capable of accurately recording, on this kilowatt-hour basis of measurement, the amount of electric power consumed in your home. The old dial type watt-hour meter and the new cyclometer watt-hour meter, as shown in Figure 2.2.B, both record the kilowatthours of electric power consumed in your home. The old dial type watt-hour meter records the kilowatthours of electric power used on six separate dials. Begin reading with the 10,000 kilowatt-hour dial and read each dial down through the 1/10 kilowatt-hour dial. Read the number starting at zero, clockwise or counterclockwise, that the pointer has just passed over. The reading on the 10,000 dial is 2, the 1,000 dial 3, the 100 dial 4, the 10 dial 7, the 1 dial 8 and the 1/10 dial 6. The number of kilowatthours that the meter shows is 23478.6. The new cyclometer type is a direct reading meter that shows the total number of kilowatthours of electric power consumed. The last digit, shown in the window on the right, is read as a tenth.

The watt-hour meter is supposed to be read each month by a meter reading man from the light and power company. To determine the exact amount of electricity consumed in one month, the billing office in the light and power company subtracts last month's meter reading from the present month's meter reading. If, for example, last

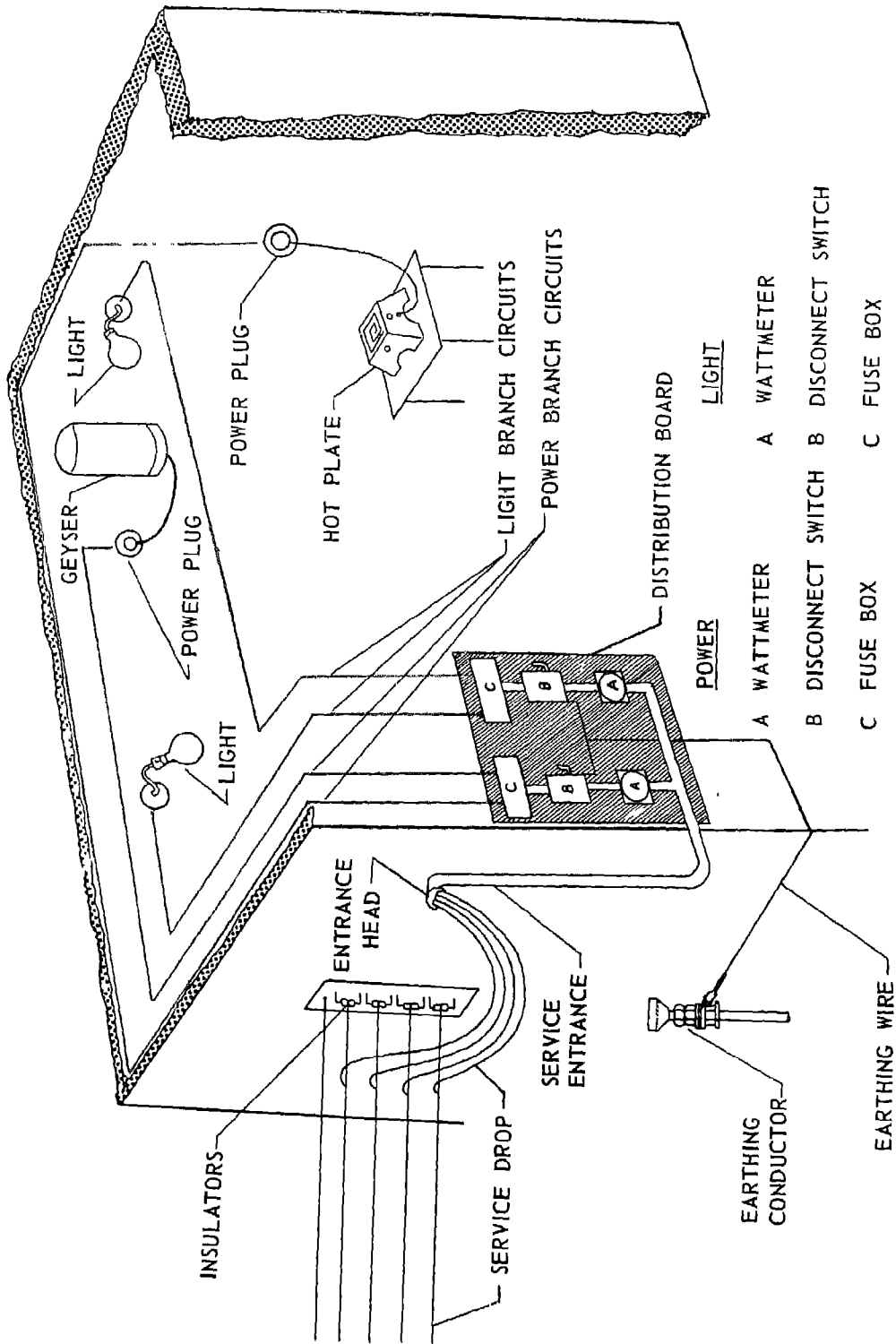
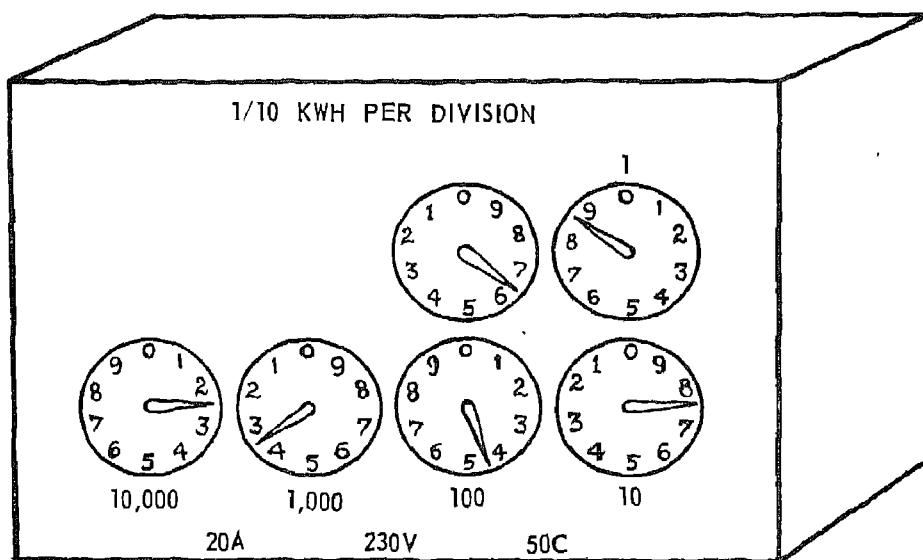
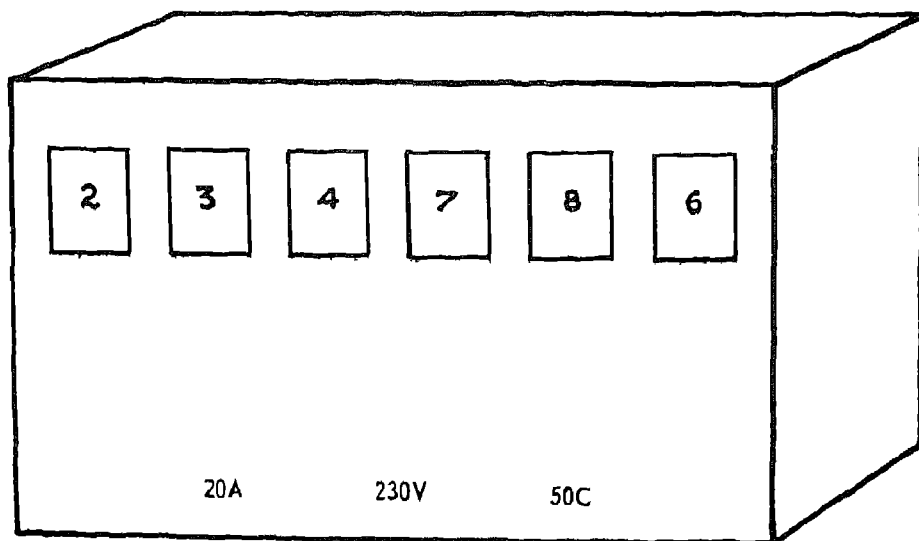


Fig. 2 2.A. House Wiring System

**DIAL TYPE****CYCLOMETER TYPE****Fig. 2.2.B, Watthour Meters**

month's reading of 23,408.6 is subtracted from the present month's reading of 23,478.6 the total amount of kilowatthours consumed for the month is 70.

The light and power company charges a different rate for 'light' and 'power'. The rate of charge for 'light' and 'power' may also vary in different parts of India.

LIGHT RATE

1st	40 Kilowatts	@	18 Paisa
2nd	80 Kilowatts	@	20 Paisa

POWER RATE

1st	50 Kilowatts	@	8 Paisa
2nd	150 Kilowatts	@	12 Paisa

The electric power company's bill based on either 70 kilowatts of light or 70 kilowatts of power consumed in one month would be :

LIGHT BILL

40 Kilowatts	×	18 Paisa	=	7.20
30 Kilowatts	×	20 Paisa	=	6.00
				Rs. 13.20

POWER BILL

50 Kilowatts	×	8 Paisa	=	4.00
20 Kilowatts	×	12 Paisa	=	2.40
				Rs. 6.40

The *disconnect switches* for the main line, as shown in Figure 2.2A, should be connected directly to the watt-hour meters. The disconnect switch is actually a safety device because, if there is an electrical hazard in the house, it permits all electricity to be shut off. The disconnect switch, as shown in Figure 2.2.C, also has its own safety device built into the box cover. The switch handle is so designed that the box cover cannot be opened with the switch in the 'ON' position. Notice that in the illustration with the handle in the 'OFF' position, when the box cover is opened,

the *knife switches* are disconnected. The electric wires leading into the bottom of the disconnect switch box, if they are not enclosed in conduit, should be protected with a *ceramic bush*. It is considered a safe practice to have all wires entering or leaving a metal box always protected with a ceramic bush. The electric wires are first connected to the knife switches and then to the main *fuses*. Notice that where the wires leave the top of the box they are again protected from the metal by a ceramic bush.

The *fuse box*, as shown in Figure 2.2.A, is connected directly to the disconnect switch box. The fuse box, as shown in Figure 2.2.D, should have enough fuses to adequately protect all the outlets, fixtures and appliances in the house.

Fuses are used in all electrical systems as safety (Protective) devices. A *fuse* is a soft piece of metal wire that will melt when it reaches a specified temperature. The normal size fuse wire used in the average house is rated as 5, 10, 15 or 30 amperes. This means that each specifically rated fuse wire will carry up to its rated ampere capacity before overheating and burning out. Therefore, the fuse can be considered as a safety switch because, when it melts, it automatically opens the circuit and stops the flow of electricity. This gives the houseowner a warning that something is wrong. He then has the opportunity to have a competent electrician make the necessary repairs. Notice that where the wires enter and leave the fuse box they are again protected from the metal by a ceramic bush.

The *fuse carrier*, as shown in Figure 2.2.D, is removable from the fuse box. Always, as a safety precaution, pull the disconnect switch to the 'OFF' position before removing a fuse carrier. The fuse carrier used in the average house electrical system with a 5, 10, 15, or 30 ampere fuse wire is rated at a maximum of 250 volts. Fuse carriers used in some houses with special electrical requirements are for 30, 60 and 100 ampere fuse wire and are rated as a maximum of 500 volts.

Fuse wire wrapped on a cardboard form is sold in small quantities for home use. To properly wire a fuse carrier without wasting any of the

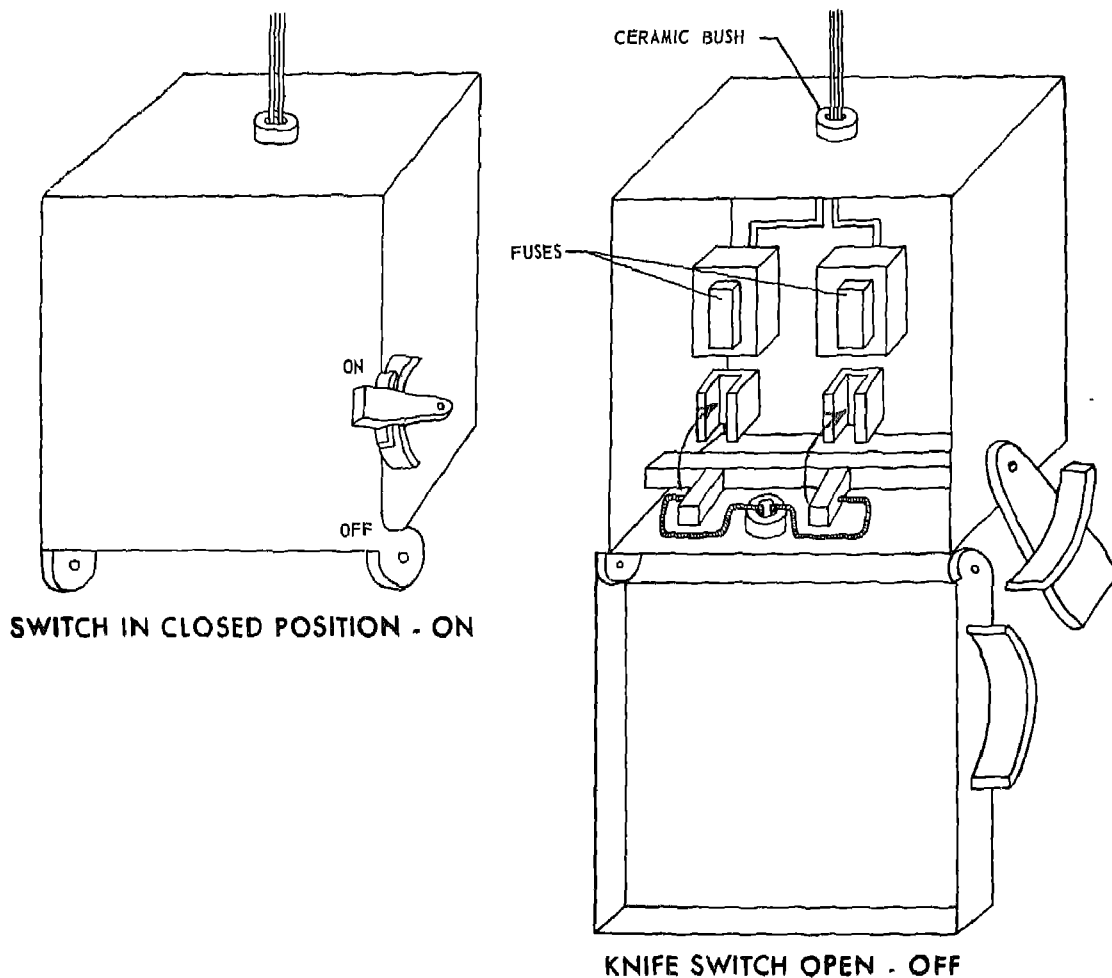


Fig. 2.2.C. Disconnect Switch

fuse wire, as shown in Figure 2.2.E, insert the loose end of the fuse wire through the hole in the base. Wrap the loose end of the wire around the bolt, underneath the washer, and in the direction of tightening the bolt. Then tighten the bolt securely. Wrap the fuse wire in the direction of tightening, while still fastened to the cardboard form, underneath the washer of the other bolt. Tighten the bolt securely and break off the fuse wire close to the bolt.

The *branch circuits*, as shown in Figure 2.2.A, are the individual wires that lead from the fuse

boxes to the electric appliances. The 'light' and 'power' each have their own branch circuits. Branch circuit, as the name implies, means that the electricity coming in the heavy service drop wires branches off at the distribution board into lighter wires that will service different sections of the house. In modern house wiring care is taken to have enough separate circuits to avoid overloading any one circuit. Therefore it is recommended, from the standpoint of electrical safety, that 'light' and 'power' each have two to six circuits. This depends upon how many kilowatts

of power the electric company has allocated to the house. An excellent practice is to have a 'light' and 'power' branch circuit for each room in the house. This provides the opportunity for the use of more appliances in the future, without concern about overloading any one branch circuit.

The *earthing wire*, as shown in Figure 2.2.A, connects the metal frames of all the boxes directly to the ground. This wire provides a path for electricity to follow directly into the ground through the earthing conductor, if a 'live wire'

touches any of the metal boxes. Electricity follows the path of least resistance; therefore, instead of the electricity flowing through you it travels directly into the ground. Each metal box or appliance can be connected internally with each other by a wire; therefore, they all become connected directly to this one earthing connection. The earthing wire is a safety protection device that grounds the entire electrical system to the earth. One might compare the safety protection of the earthing wire in the electrical system to that of the lightning arrestor. It has no direct

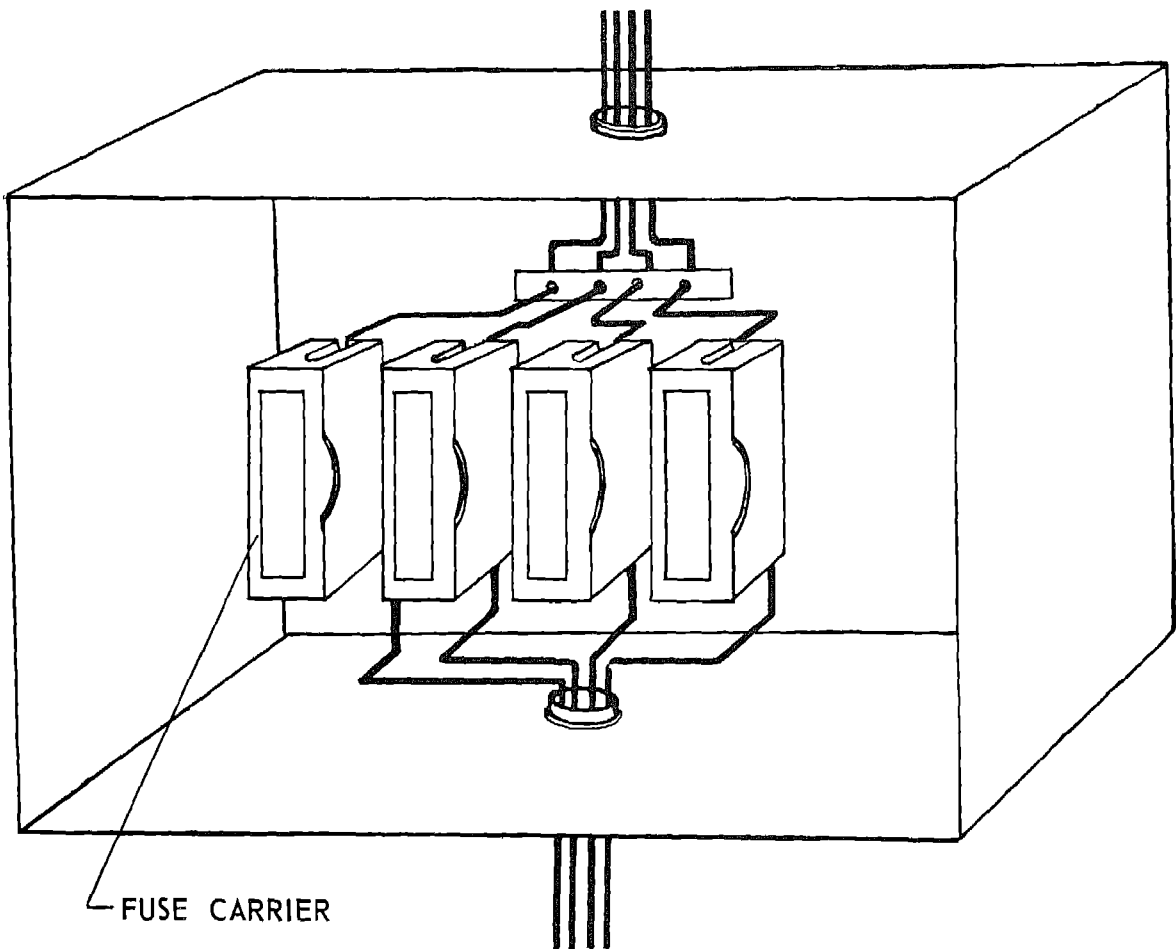


Fig. 2-2-D. Fuse Box

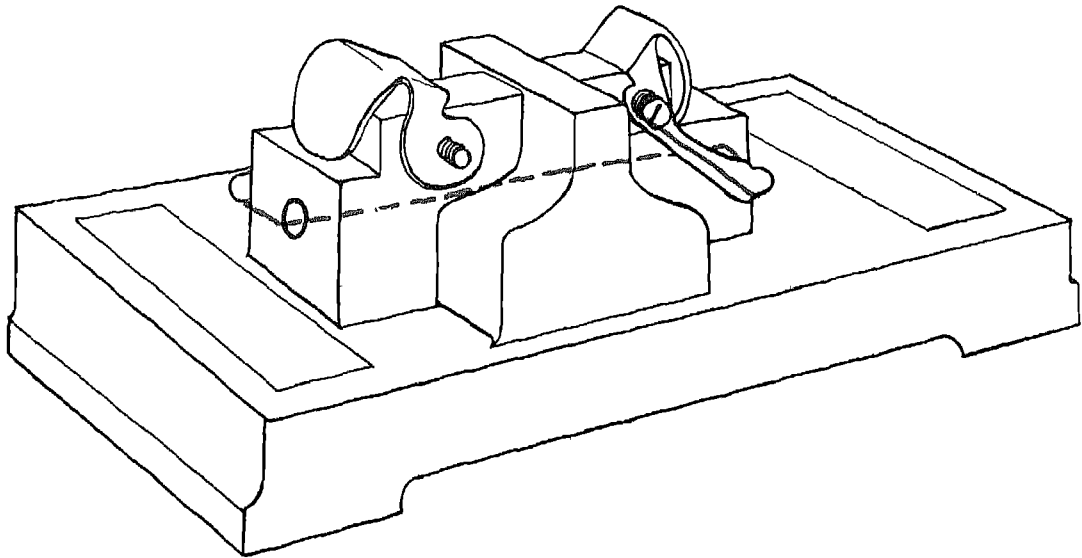


Fig. 2.2.E. Wired Fuse

function in the continuous flow of electricity, but when a short circuit occurs and it is needed, it is there. According to the Indian Standards Institution, all household appliances should be provided with and connected to an earthing wire connection.

3. ELECTRICITY AT WORK

3.1 Alternating Current

The type of current generated by Indian power stations is called *alternating current*. The principle of alternating current can be pictorially explained, as shown in Figure 3.1.A, by a bouncing ball. The bouncing ball first travels in one direction and then reverses itself and travels in the opposite direction. Alternating current, the same as the bouncing ball, first travels in one direction and then reverses itself and travels in the opposite direction. Each time the ball bounces

back, having travelled in two directions, it has made one complete *cycle*. The same is true with alternating current, having travelled in two directions, it has made one complete cycle. If you can imagine speeding the bouncing ball up to 50 complete cycles per second, you can understand the principle of 50 cycle alternating current. The 50 cycle alternating current, which is generated by power stations in India, means that the alternating current makes 50 complete cycles every second. Alternating current, for convenience, is generally abbreviated into the initials A.C.

3.2 Electric Measurement

Electrical measurement, as it usually applies to the home, requires the understanding of four technical terms. These four technical terms may be better understood perhaps, if they are compared to something visual such as the flow of water through an irrigation canal.

ELECTRICITY

- (1) Volt—The force, in this case the volt, that pushes the electricity through a wire.
- (2) Resistance—The tendency of a substance, such as a wire, to oppose the flow of electric current. The unit of measurement in this case, the *ohm*, will be used to measure the amount of resistance in a circuit.
- (3) Ampere—The rate of flow of current through an electric circuit. The unit of measurement in this case, the *ampere* is used to measure the total amount of amperage flowing through the electrical circuit.
- (4) Watt—The power consumed in an electric circuit. The unit of measurement in this case, the *watt*, will be used to measure the amount of power consumed in the circuit.

WATER

- (1) Volt—The force, in this case gravity, that pushes the water through a canal.
- (2) Resistance—The tendency of a substance, such as a stone, to resist the flow of water through the canal. The unit of measurement in this case, a selected size stone, could be used to measure the amount of resistance to the flow of water in a canal.
- (3) Ampere—The rate of flow of water through a canal. The unit of measurement in this case, a selected rate of water flow, could be used to measure the total amount of water flowing through a canal.
- (4) Watt—The amount of water consumed in irrigation. The unit of measurement in this case, a selected amount of water, could be used to determine the total amount of water consumed in irrigation.

Two formulae are used in electricity in computing electrical measurements. The formulae and their symbols are: $E=I \times R$ and $W=E \times I$; (E = Volts, I = Amperes, R = Resistance, W = Watts).

The first formula, which is used to determine the amount of volts, current or resistance in an electrical circuit, may be expressed mathematically in three ways.

 $E=I \times R$ FORMULA

$$E=I \times R \qquad I=\frac{E}{R} \qquad R=\frac{E}{I}$$

Let us assume for purposes of discussion that $E=220$ volts, $I=10$ amperes and $R=22$ ohms resistance. Then, any of the above formulae can be solved as long as two of the electrical factors are known. Each formula given below with computations, shows how to find an electrical unknown when two factors are known.

$$\begin{array}{lll} E=I \times R & I=\frac{E}{R} & R=\frac{E}{I} \\ E=10 \times 22 & I=\frac{220}{22} & R=\frac{220}{10} \\ E=220 & I=10 & R=22 \end{array}$$

The second formula which is used to determine the amount of power consumed in an electrical circuit may be expressed mathematically in three ways.

 $W=E \times I$ FORMULA

$$W=E \times I \qquad E=\frac{W}{I} \qquad I=\frac{W}{E}$$

Let us assume for purposes of discussion that $W=2,200$ watts, $E=220$ volts and $I=10$ amperes. Then, any of the above formulae can be solved as long as two of the electrical factors are known. Each formula given below with computations, shows how to find an electrical unknown when two factors are known.

$$\begin{array}{lll} W=E \times I & E=\frac{W}{I} & I=\frac{W}{E} \\ W=220 \times 10 & E=\frac{2200}{10} & I=\frac{2200}{220} \\ W=2,220 & E=220 & I=10 \end{array}$$

3.3 Series Circuits

In a series circuit there is only one path (wire) through which current can flow. Each load (such as a lamp) is connected in series, one after the other. Water for irrigation could be compared to this, as shown in Figure 3.3.A, if the irrigation ditch feeds into a series of fields, one after the other. If the irrigation ditch feeding a

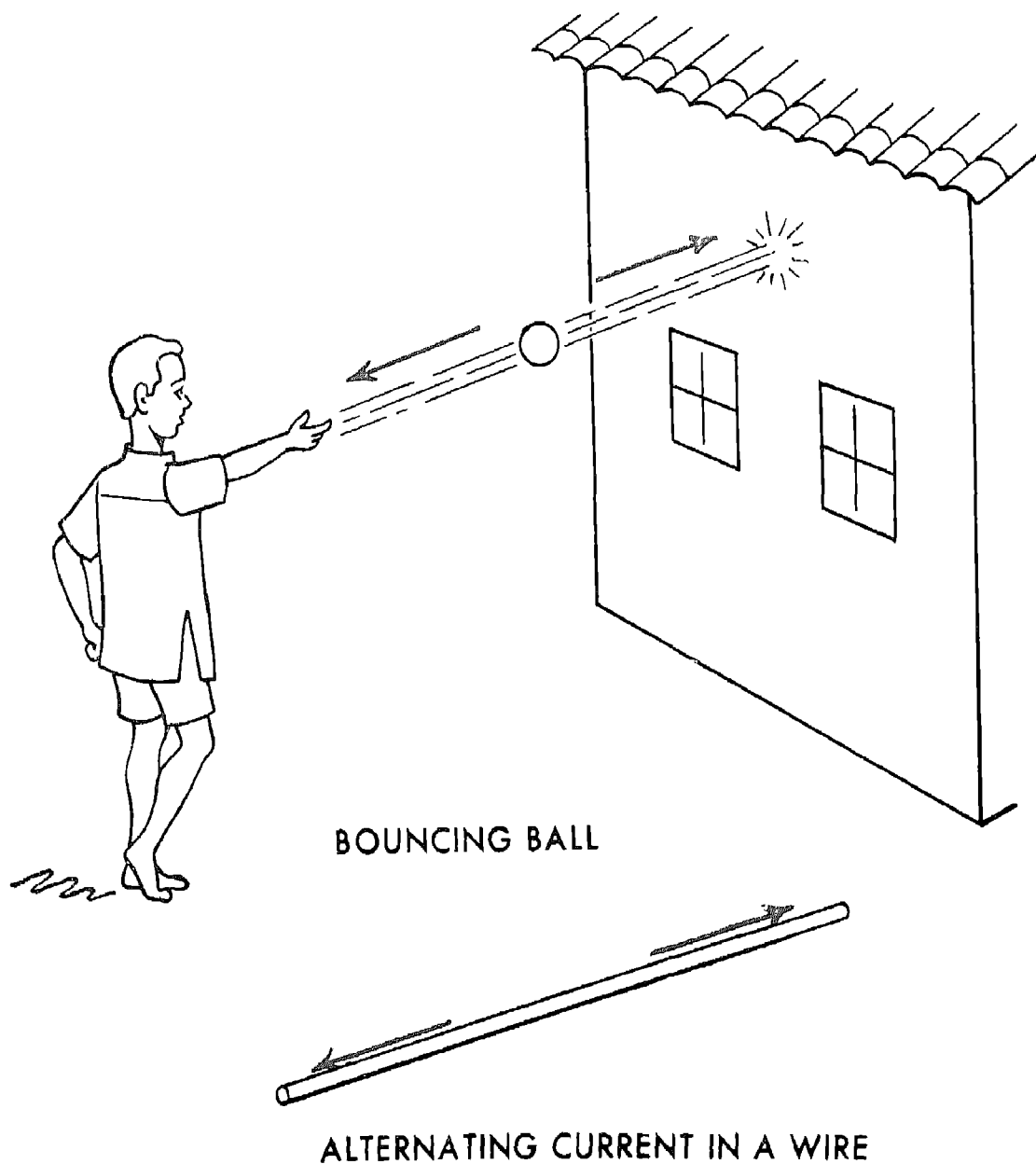


Fig. 3.1.A, Principle of Alternating Current

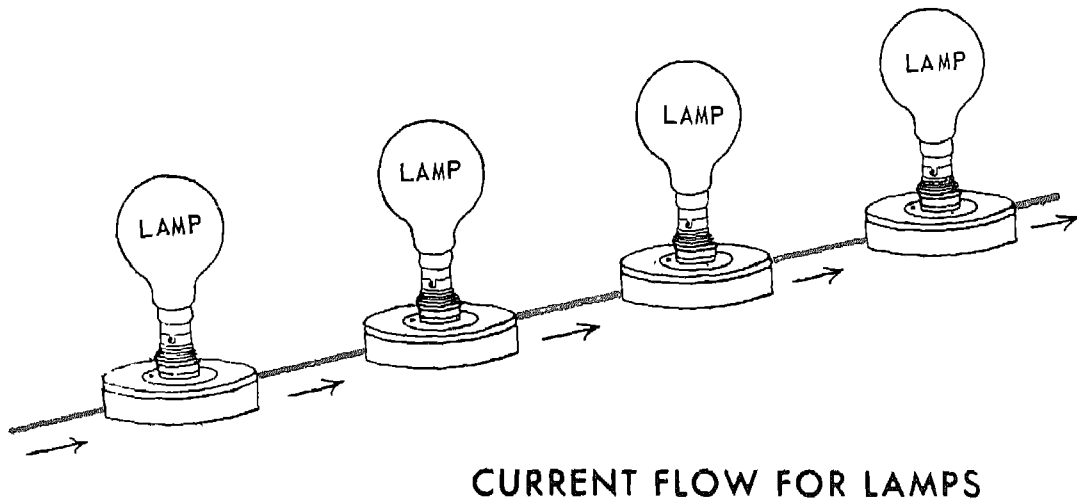
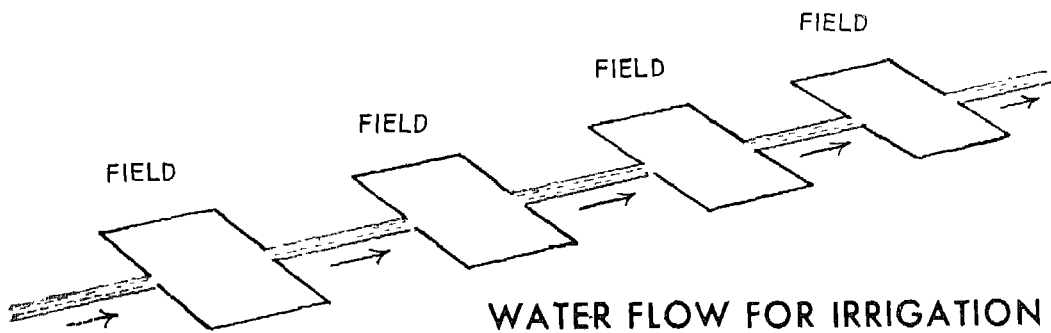


Fig. 3.3.A. Series Circuit—Comparison of Irrigation Water Flow to Current Flow

series of fields is closed off at any one point, the water ceases to continue to flow. If a lamp bulb in a series circuit burns out, the circuit is opened and the current ceases to flow. This is why all the lamps in a series circuit go off when one of them burns out.

Voltage—The total voltage in a series circuit is equal to the sum of each of the loads. The lamp, fan and hot plate, as shown in Figure 3.3 B, are

each rated at 220 volts and require a total of 660 volts to operate the circuit. The voltage across each load, such as the 220 volt lamp; is called the *voltage drop*. The line voltage required in a series circuit becomes higher with each apparatus (Lamp, Fan and Hot Plate) that is added. Such high voltage would be very dangerous in a house. Therefore, series circuits are not used in house wiring.

LAMP $E = I \times R$
 $E = 2 \times 110$
 $E = 220$

FAN $E = I \times R$
 $E = 4 \times 55$
 $E = 220$

HOT PLATE $E = I \times R$
 $E = 8 \times 27.5$
 $E = 220$

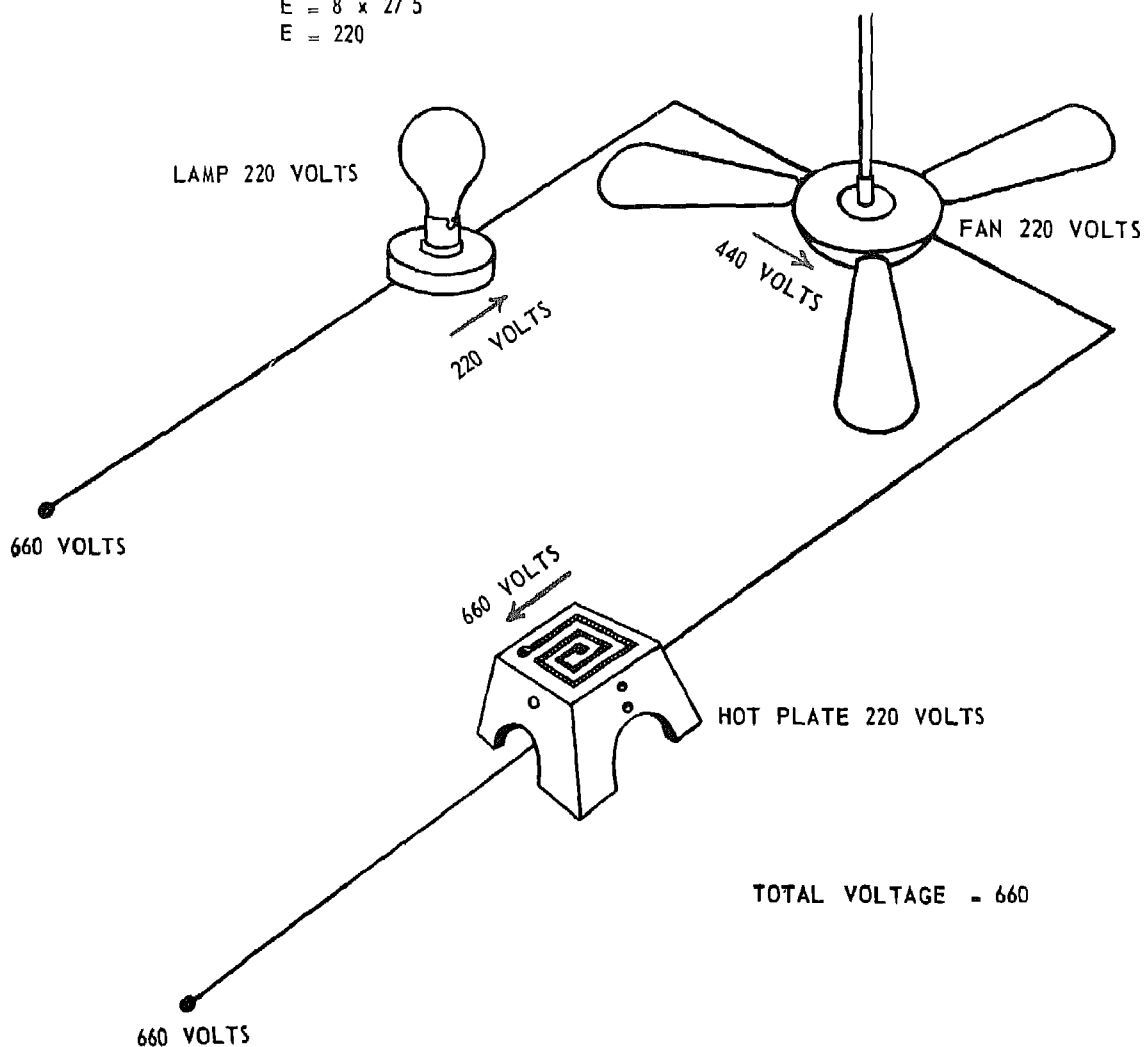


Fig. 3.3.B. Voltage in a Series Circuit

HOUSE WIRING

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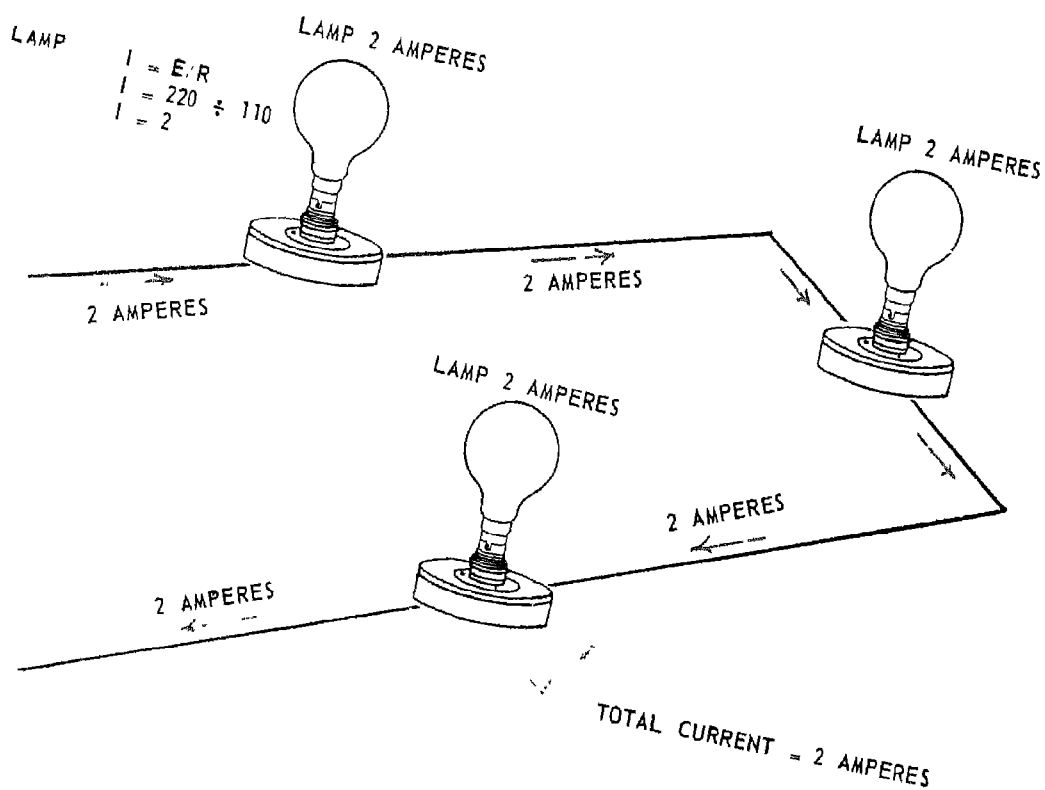
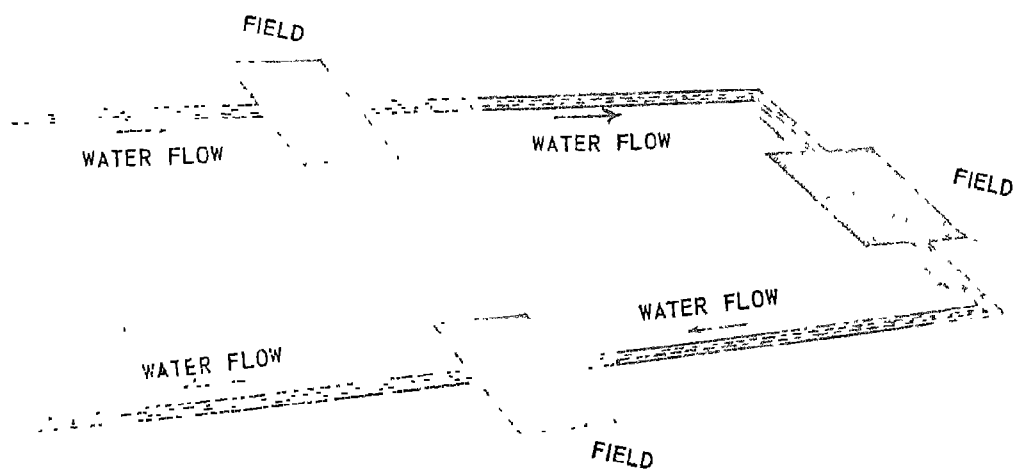


Fig. 3.3.C. Current in a Series Circuit

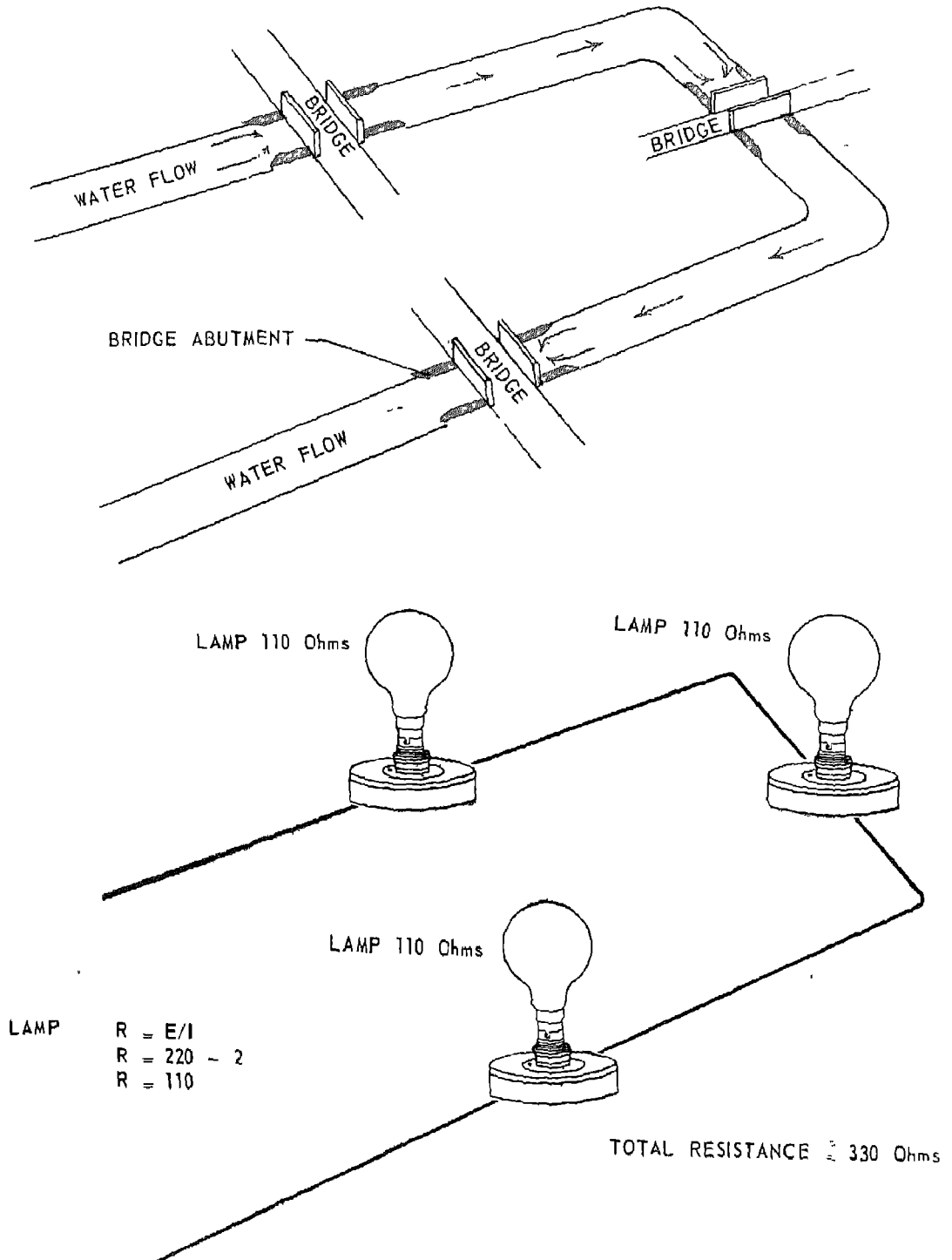


Fig. 33.D. Resistance in a Series Circuit

Current—The amount of current flow in a series circuit is the same in all parts of the circuit. This concept may be visualized by the equal flow of water through an irrigation system, as shown in Figure 3.3.C, if the irrigation ditches and fields are of the same size. It should be noted that all apparatus in a series circuit must operate on the same amount of current. This is not practical in house circuits since both small and large apparatus must work together.

Resistance—The total resistance in a series circuit is equal to the sum of each resistance in the circuit. This concept may be visualized by the resistance to the flow of water through a canal, as shown in Figure 3.3.D, as it strikes one bridge abutment after the other. The resistance of each bridge abutment would be added together to determine the total resistance to the flow of water. When all the apparatus in a circuit have the same resistance, as shown in the lamp example, the total resistance may be found by adding the resistance of each apparatus together. The formula for finding the total resistance of a series circuit when all the resistances are of equal value is :

$$R_t (\text{Total Resistance}) = R_1 + R_2 + R_3 + \dots$$

$$R_t = 110 + 110 + 110 = 330 \text{ Ohms}$$

The symbols $R_1 + R_2 + R_3 + \dots$ represents the different resistances in the circuit.

3.4 Parallel Circuit

In a parallel circuit there are two paths (two parallel wires) through which the current flows. Each load (such as a lamp) is connected between the two wires. Each load and their connecting wires are known as the *branches of the circuit*. Water for irrigation could be compared to this, as shown in Figure 3.4.A, if each field is connected between the irrigation ditches by lateral ditches. If a lateral ditch feeding any one field is closed off, water still continues to flow to all the other fields. If a lamp bulb in a parallel circuit burns out, only that branch of the circuit is opened. This is why in a parallel circuit when one lamp burns out all of the rest of the lamps remain on.

Voltage—The voltage across each branch of a parallel circuit is the same as that of the main line. Therefore, each load, such as a lamp, fan or hot plate, as shown in Figure 3.4.B, operates on the same voltage as the main line. This implies that all apparatus used in a house that has a 220 volt service, must be rated at 220 volts. Lamps and other consuming apparatus may be turned on and off as desired, without changing the voltage in the circuit. The only exception to this is that a slight voltage drop may appear in the line as each additional apparatus is switched on. However, the voltage drop is negligible if the conductors (wires) are adequate in size and not overloaded.

Current—The total current in a parallel circuit is equal to the sum of the branch circuits. If, for example, only the lamp is turned on, as shown in Figure 3.4.C, the total current in the circuit will be 2 amperes. If the lamp and fan are turned on, the total current in the circuit will be 6 amperes. If the lamp, fan and hot plate are turned on, the total current in the circuit will be 14 amperes. This means that as each apparatus in a house is turned on, it adds to the total current in the circuit.

Resistance—The total resistance of a parallel circuit is always less than the value of the lowest resistance in the circuit. Therefore, the total resistance of a parallel circuit, as shown in Figure 3.4.D, decreases as each apparatus is added. This is because a parallel circuit provides more paths through which the current can flow.

The resistance of a single light by Ohm's law is :

$$R = \frac{E}{I} = \frac{220}{2} = 110 \text{ Ohms}$$

This is also the resistance of the entire circuit when only one lamp is lighted. If two lamps are burning, the resistance of each lamp is the same as before. But, the resistance of the entire circuit is now :

$$R = \frac{E}{I} = \frac{220}{4} = 55 \text{ Ohms}$$

This shows that the resistance in a parallel

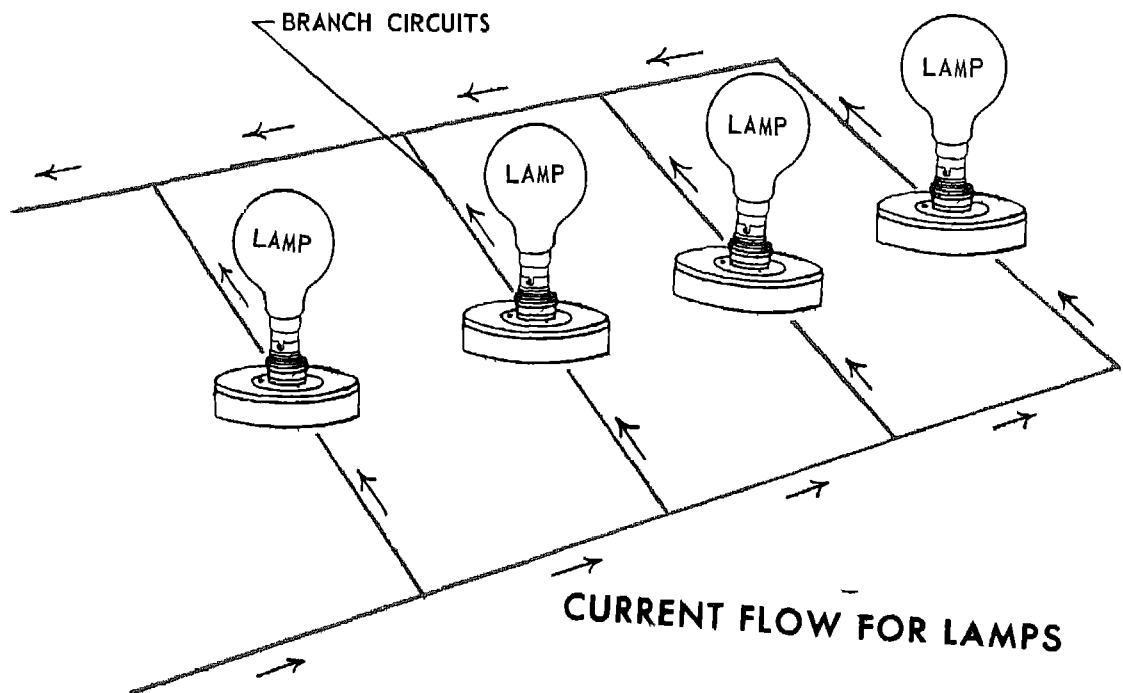
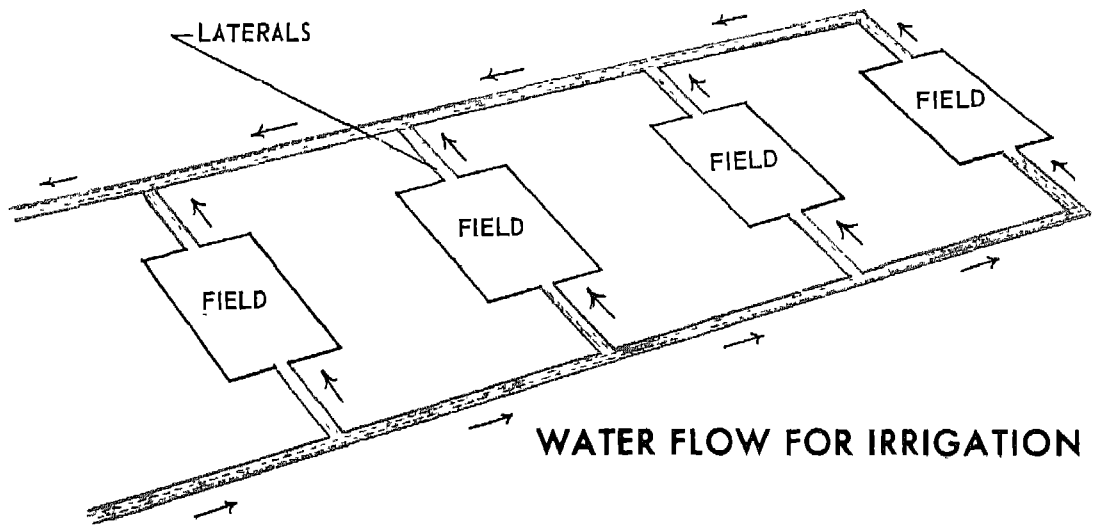


Fig. 3.4.A Parallel Circuit—Comparison of Irrigation Water Flow to Current Flow

LAMP $I = E/R$
 $I = 220 \div 110$
 $I = 2$

FAN $I = E/R$
 $I = 220 \div 55$
 $I = 4$

HOT PLATE $I = E/R$
 $I = 220 \div 27.5$
 $I = 8$

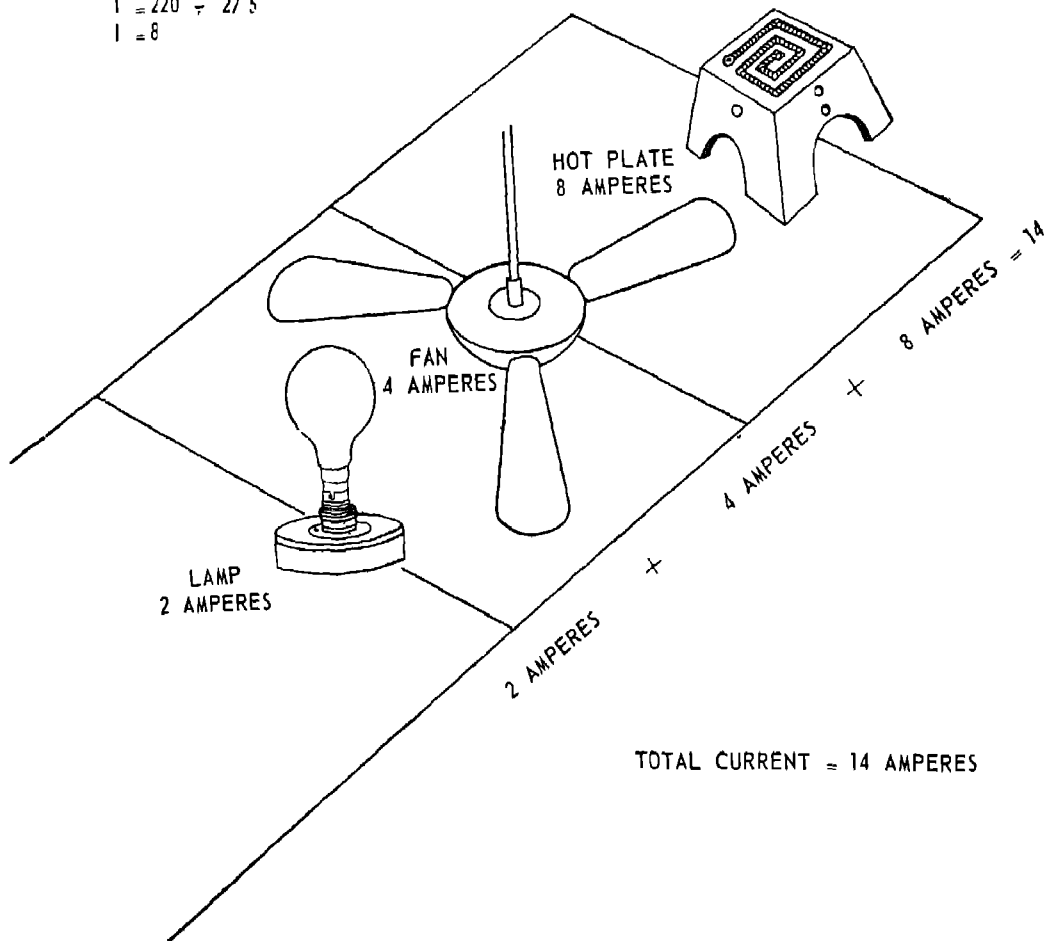


Fig. 3.4.C. Current in a Parallel Circuit

LIGHT $R = E/I$
 $R = 220 \div 2$
 $R = 110$

FAN $R = E/I$
 $R = 220 \div 4$
 $R = 55$

HOT PLATE $R = E/I$
 $R = 220 \div 8$
 $R = 27.5$

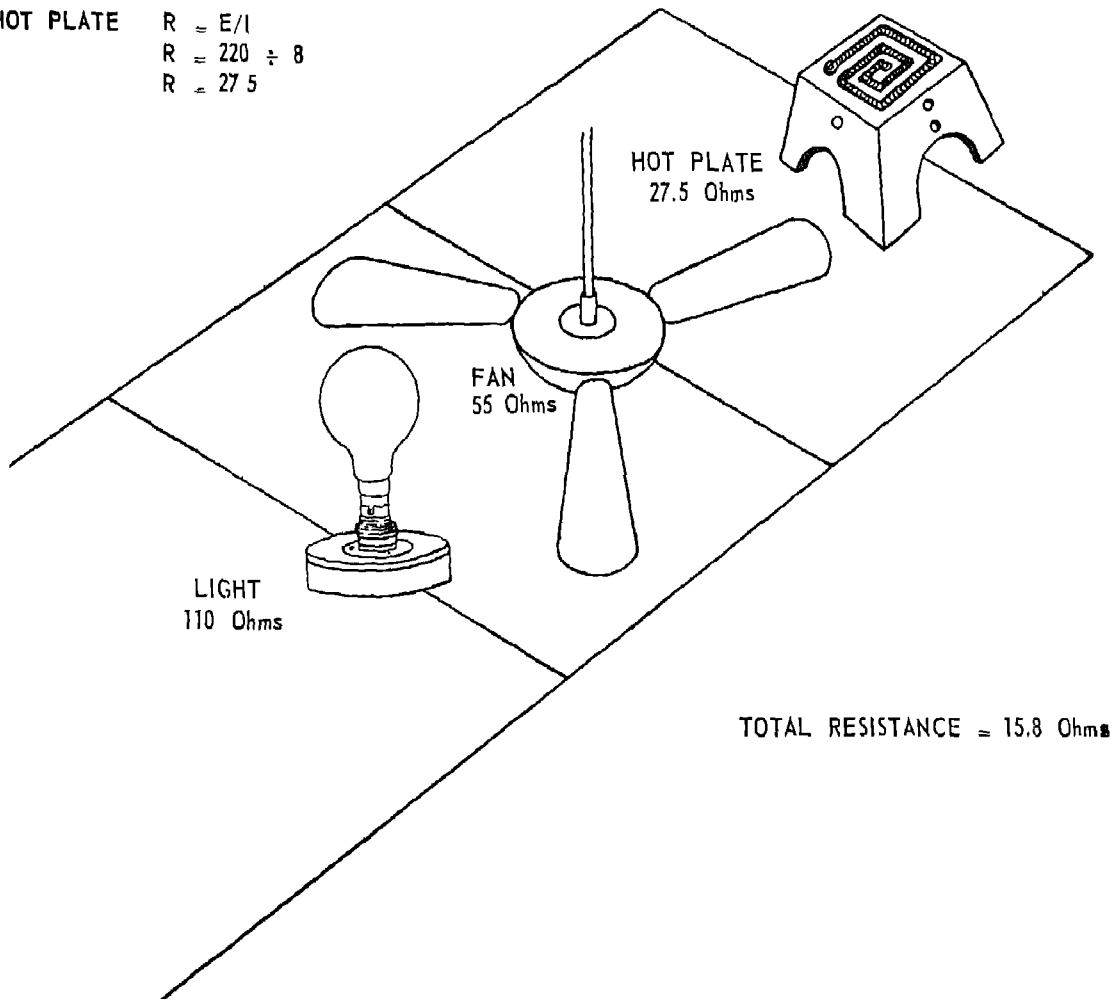


Fig. 3.4,D. Resistance in a Parallel Circuit

circuit decreases when the load increases. When all apparatus in a circuit have the same resistance, as shown in the circuit example, the total circuit resistance may be found by dividing the resistance of any one apparatus by the number of such apparatus. The formula for finding the total resistance of a parallel circuit when all the resistances are of equal value is :

$$R_t \text{ (Total Resistance)} = \frac{\text{Value of Each Resistance}}{\text{Number of Resistances}}$$

$$R_t = \frac{110}{2}$$

$$R_t = 55 \text{ Ohms}$$

The formula for finding the total resistance of a parallel circuit when all the resistances are of unequal value is :

$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$R_t = \frac{1}{\frac{1}{110} + \frac{1}{55} + \frac{1}{27.5}}$$

$$R_t = \frac{1}{.009 + .018 + .036}$$

$$R_t = \frac{1}{.063}$$

$$R_t = 15.8 \text{ Ohms}$$

The symbols $R_1 + R_2 + R_3 + \dots$ each represent a different resistance in the circuit.

4. WIRE : IDENTIFYING SPLICING, SOLDERING AND TAPING

4.1 Identification

Electric wires (conductors) are manufactured in a variety of materials, shapes, sizes and with various insulation coverings.

The material most commonly used for house wire is copper. Copper is a good electrical conductor and carries current easily. Its resistance is very low, therefore, only a small voltage is

consumed as the current flows through the wire. Because copper has a low resistance very little heat is produced in the wire.

The shape of the most commonly used wire is round. However, wires are made in other shapes such as, flat, square, rectangular and hollow. Round wire is used extensively for house wiring because it can easily be bent around corners, mounted on walls externally, or pulled through conduit (pipe) as internal wiring in a wall.

The size of a wire is measured with a gauge, as shown in Figure 4.1.A, called a wire gauge. The *wire gauge* measures the diameter of a wire according to a standard gauge number assigned to each size wire. It should be noted that the higher the gauge number assigned the smaller the diameter of the wire. It could also be expressed as, the lower the gauge number assigned the larger the diameter of the wire. The data of a few selected wire sizes are shown in Table 1.

TABLE I
COPPER WIRE DATA

Gauge	Diameter of wire	Resistance in Ohms for 100 feet of wire	Current carrying capacity in Amperes
18	.040	651	3
16	.051	.409	5
14	.064	.258	15
12	.081	.162	20
10	.102	.102	30

Insulation is necessary on most electric wires to avoid *short circuits*. The wires used in electrical circuits in a house are covered with insulation so that they can be placed next to each other without causing a short circuit. Exposed bare wires would also be very dangerous to people who might innocently come into contact with them. Most house wires are insulated with rubber, plastic, or a cotton cover that is impregnated with a moisture and fire resistant material. The details

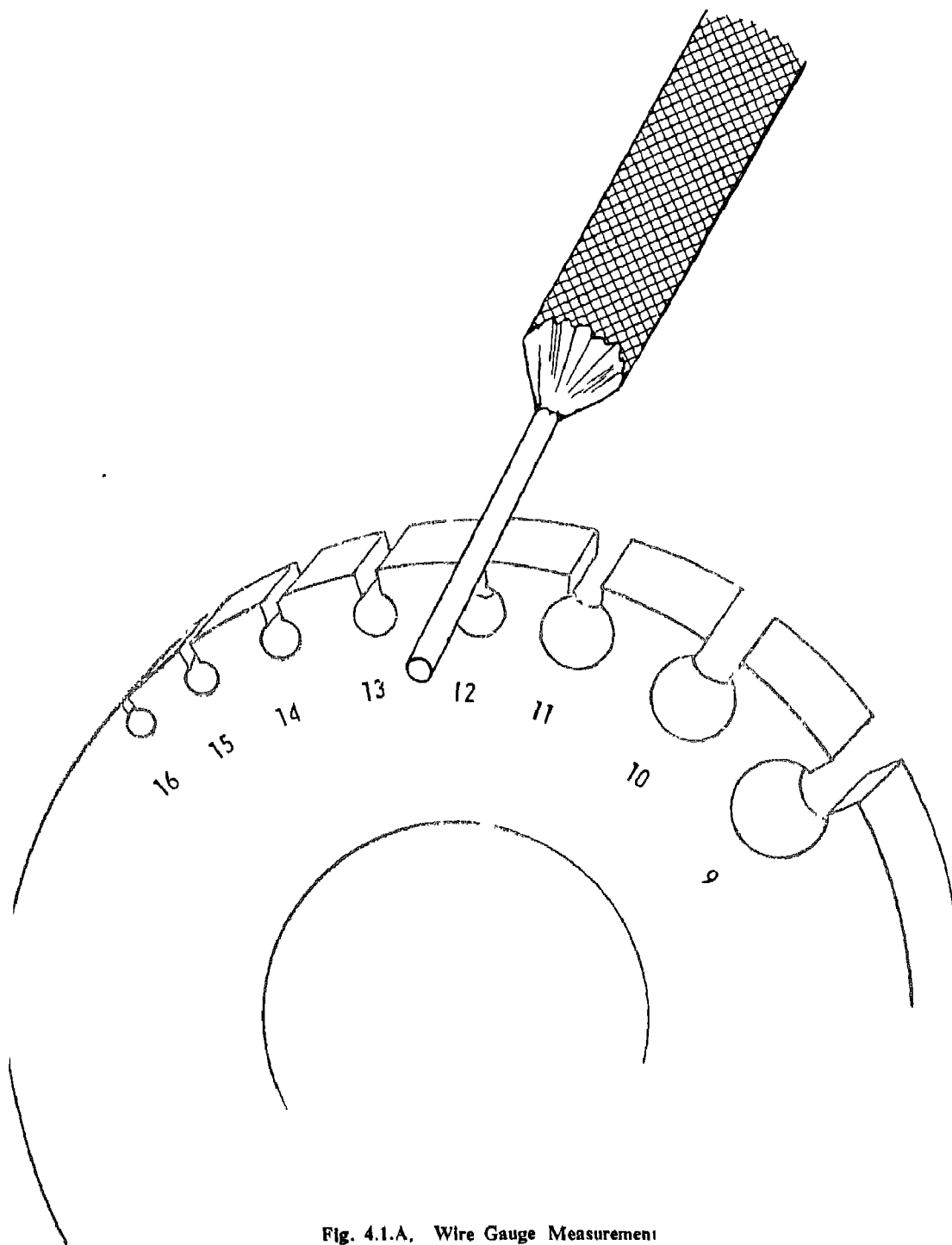


Fig. 4.1.A, Wire Gauge Measurement

TABLE II
HOUSE WIRE DATA

TYPE	USE	MOUNTING	GAUGE		Amperes	Volts	CORD			Reel	Coil
			Solid	Twisted Strand			Single	Double	Triple		
VIR	Main Power	Concealed		7/16	50	250 and 500	Rubber Covered with impregnated cotton		Yes		
				7/18	35						
	Power Sockets	Concealed		7/20	30						
				7/22	15						
	Light	Concealed		3/20	10						
				3/22	5						
CTS	Bell	Concealed		1/18	5	250	Rubber coated	Rubber coated	Yes		
				7/20	30						
	Power Sockets	Exposed		7/22	15						
				3/20	10						
	Light	Exposed		3/22	5						
				1/18							
FLEXIBLE WIRE	Table lamp Extension Cords Light Fixtures	Exposed		40/76	20	250		Plastic coated	Rubber coated	Plastic Coated	
				23/76	10						
GROUND WIRE	Ground Stations	Exposed	18				No Cover			Yes	
	Power Points	Exposed	14				No Cover			Yes	
	Light Points	Exposed	16				No Cover			Yes	

of the most commonly used house wires are shown in Table II. The table provides the following information :

DEFINITIONS OF HOUSE WIRE

<i>Type</i>	—The manufacturers name assigned to the wire.
<i>Use</i>	—The particular use of the wire in the electrical system of the house.
<i>Mounting</i>	—Whether the wire is designed to be concealed in conduit (pipe) or fastened on exposed wood battens.
<i>Gauge</i>	—Whether it is a solid wire or made up of twisted strands. The first number of the twisted strand wire (for example number 7) indicates the number of strands that make up the twisted wire. The second part of the number (for example number 16) indicates the gauge number of each wire strand.
<i>Amperes</i>	—The approximate maximum amperage rating assigned to the wire.
<i>Volts</i>	—The different maximum voltages for which the wire is manufactured.
<i>Cord</i>	—Whether the wire is manufactured as a single, double or triple wire; the type of insulation with which it is covered; and the type of insulation in which the wires may be sheathed.

It is interesting to note that when three separate wires are sheathed in one insulation, that usually each individual wire is covered with a black, red or green coloured insulation. This is a colour code designed as an electrical safety device, and recommended by the Indian Standards Institution. The black colour code signifies that it is the *LIVE* wire in the circuit. The red colour code signifies that it is the *NEUTRAL* wire in the circuit. The green colour code signifies that it is the *EARTHING* wire in the circuit.

Reel and Coil—Whether the wire is available in the market on large reels or smaller coils of 100 feet in length.

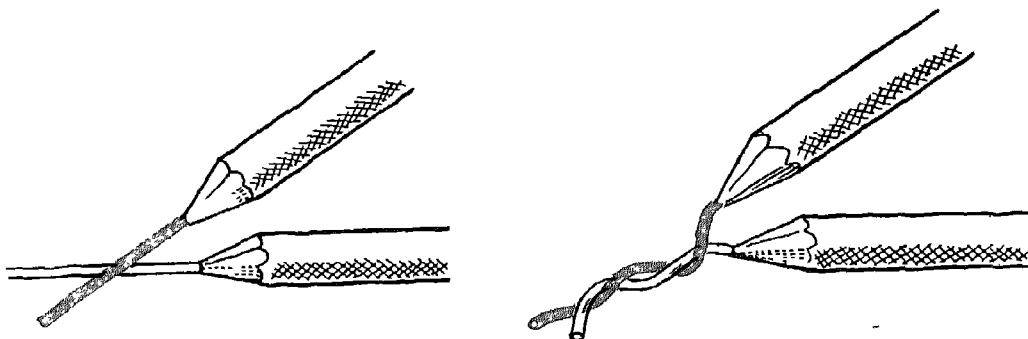
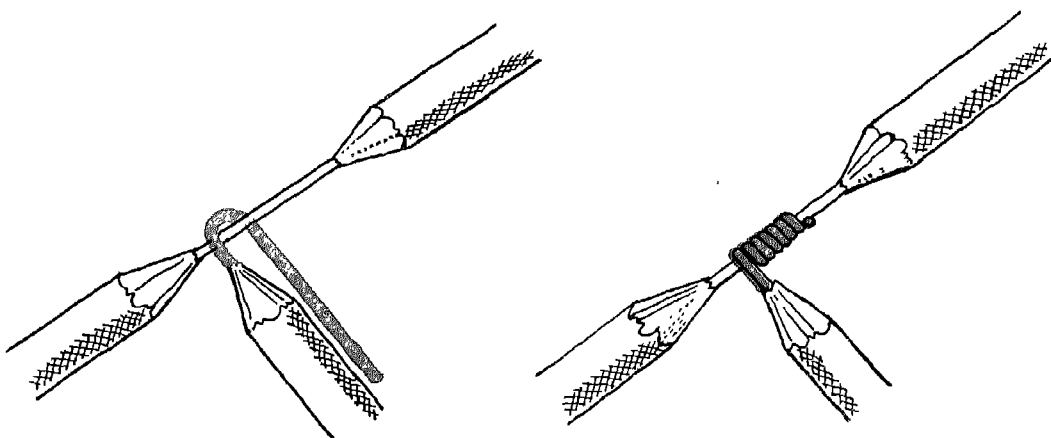
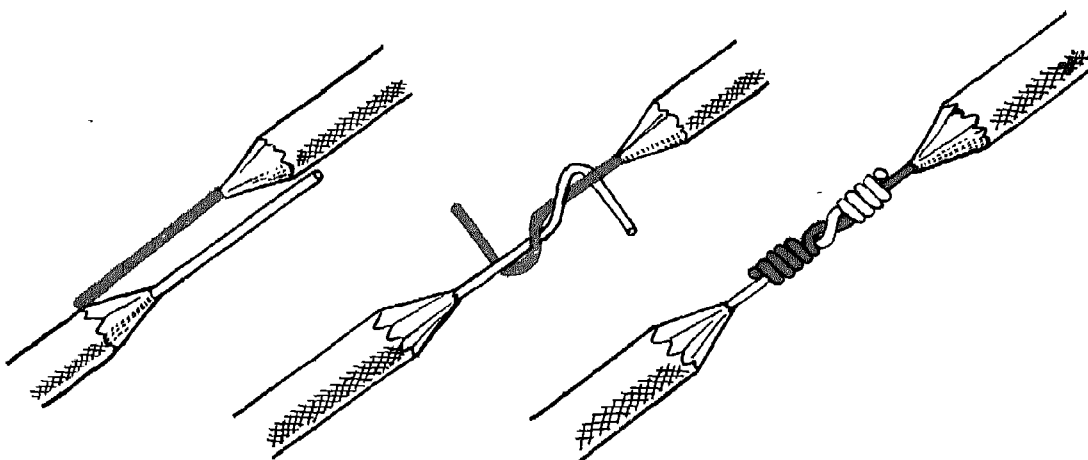
4.2 Splices

A splice is an electrical connection made by twisting wires together. A splice joins the wires, when correctly made, as if they were one continuous electrical connection. A perfect splice should be soldered to insure a good electrical connection and prevent corrosion.

Wires that are not spliced correctly make a poor electrical contact. The poor electrical contact, which creates resistance to the current flow, produces heat at the connection. If enough heat is produced the insulation will burn and cause a fire. Most house fires, more than any other electrical defect, are said to be caused by bad splices.

The three basic types of splices used in most house wiring, as shown in Figure 4.2 A, are the *pigtail splice*, *tap splice* and the *western union splice*.

- (1) *Pigtail Splice*—The pigtail splice is the easiest to make.
 - (a) Remove approximately $1\frac{1}{2}$ inches of insulation from the wire with a knife. Cut the insulation at an angle in the same manner that a lead pencil is sharpened. Do not cut nicks in the wire. Each nick in the wire, reduces the electrical carrying capacity of the wire.
 - (b) Cross the wires at a point just beyond the insulation. Clamp both wires, near the ends, with a pair of pliers and twist evenly until tight.
 - (c) Cut off, to approximately $\frac{3}{4}$ inch, the excess wire.
 - (d) Solder and tape the wire connections, as shown in the sections on soldering and taping.
- (2) *Tap Splice*—A tap splice is used when a wire needs to be joined at some point along another wire.
 - (a) Remove approximately $\frac{3}{4}$ inch of insulation at the place where the wire is to be joined. Remove approximately 3 inches of insulation from the end of the wire

**PIG TAIL SPLICE****TAP SPLICE****WESTERN UNION SPLICE****Fig. 4.2.A. Wire Splices**

to be used in making the tap splice. Scrap the wires clean. Cut the insulation at an angle in the same manner that a lead pencil is sharpened. Do not cut nicks in the wire. Each nick in the wire, decreases the size and reduces the electrical carrying capacity of the wire.

- (b) Wrap the wire to be joined around the other, until the $\frac{3}{4}$ inch space is filled with wire.
 - (c) Cut off the excess wire. Twist the tap splice evenly with pliers until tight.
 - (d) Solder and tape the wire connection, as shown in the sections on soldering and taping.
- (3) *Western Union Splice*—A western union splice is used when two wires are joined, especially under tension, to make a longer wire.
- (a) Remove approximately 2 inches of insulation from each wire with a knife. Scrap each wire clean. Cut the insulation at an angle in the same manner that a lead pencil is sharpened. Do not cut nicks in the wire. Each nick in the wire decreases the size and reduces the electrical carrying capacity of the wire.
 - (b) Cross the wires at a point about 1 inch beyond the insulation. Twist the ends of the wires at a 180 degree angle to each other. Wrap the ends of the wires around the other until the space is filled with wire.
 - (c) Cut off the excess wire. Twist the western union splice evenly with pliers until tight.
 - (d) Solder and tape the wire connections, as shown in the sections on soldering and taping.

4.3 Soldering

Soldering insures good electrical conductivity in a wire because it *bonds* the joint together as one continuous conductor. It also prevents corrosion because it seals the joint from air and

moisture that eventually would cause poor electrical conductivity.

The electrical surfaces to be joined must be clean and bright for the solder to properly bond with the joint. The dark surface on some metal is oxide. It is formed by the surface of the metal uniting with the oxygen in the air. Sometimes the insulation on the wire also leaves dirty greasy film on the wire. No matter what the cause, the surfaces must be clean and bright before being placed together for soldering. The surfaces to be joined can usually be cleaned by scraping with a knife, or rubbing with steel wool or fine abrasive paper.

The *soldering copper* is a solid piece of copper pointed at one end, as shown in Figure 4.3 A, and fastened to a steel rod with a wood handle. The soldering copper is heated in a gasoline, oil or charcoal fire. The most suitable soldering copper for electrical work, however, is the *electric soldering copper* or the *electric soldering gun*. The electric soldering copper, as long as it is connected to a source of power, has the advantage of staying at an even and continuous soldering temperature.

The electric soldering gun, by squeezing the trigger, provides instantaneous heat. It is exceptionally useful in soldering numerous small electrical connections. It is also equipped with small lamps that shine a beam of light on the work being soldered.

Flux is a chemical material that cleans the metal and helps the solder to flow. *Rosin* powder is the best type of flux for electrical connections. It helps to solder tin and copper joints very well and leaves no *acid* residue that will attack and eat the metal.

The best solder for electrical work is *soft solder*. Soft solder is made of one half lead and one half tin. Therefore, it is also called *half and half solder* or *fifty-fifty solder*. Solder must also have a lower melting point than the metals to be joined. Soft solder, which melts at about 200° centigrade, serves this purpose very well when soldering thin electrical wires. The low temperature also helps to prevent burning of the insula-

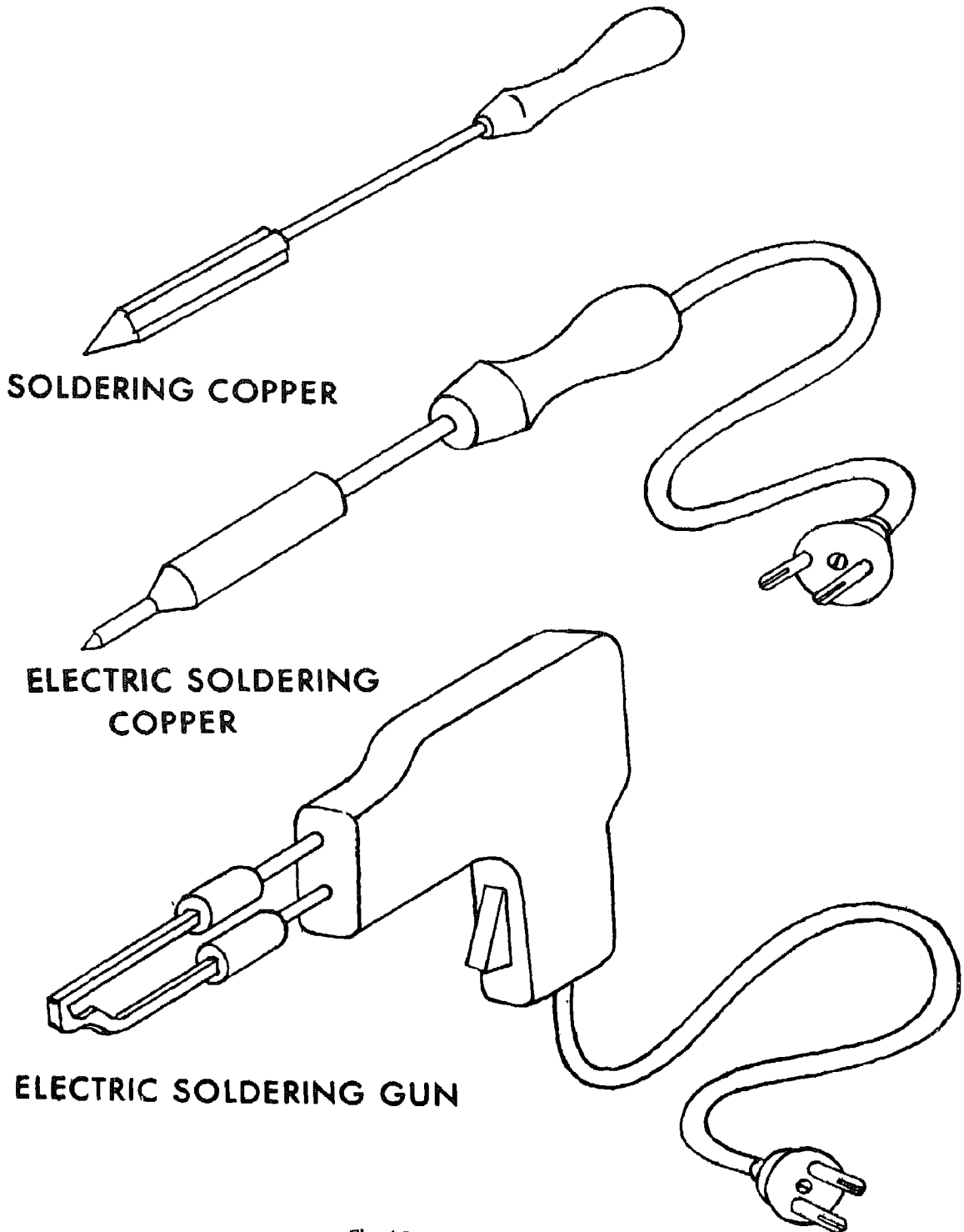


Fig. 4.3-A-Soldering Coppers

tion on the electric wire. Solder is manufactured in bar, strip or wire form. The most handy type solder to use, for electric work, is the hollow core wire in which the center is filled with rosin flux.

Tinning the soldering copper is a process of cleaning the tip and coating it with solder. For most efficient use the soldering copper must be kept clean. The steps to follow in cleaning are :

- (1) File the pointed tip of the soldering copper until it is clean and bright.
- (2) Heat the soldering copper until it is hot enough to melt solder. DO NOT heat it red hot. Excess heat causes burning, oxidation and pitting.
- (3) Clean the tip chemically by dipping it in zinc chloride, rubbing it on a salammoniac block or in flux.
- (4) Apply solder to the tip of the soldering copper, after it has been properly prepar-

ed, and the solder should melt and run smoothly around the tip.

When the joint has been carefully prepared and the soldering copper properly tinned the electrical connection can be easily soldered. The following procedure is recommended for soldering with a soldering copper :

- (1) Heat the soldering copper until the tinning on the tip melts.
- (2) Dip the soldering copper into powdered rosin.
- (3) Apply a small amount of solder to the tinned tip.
- (4) Place the soldering tip underneath the joint to be soldered and heat the joint.
- (5) Apply rosin flux to the heated joint.
- (6) Apply solders, as shown in Figure 4 3.B, to the top of the heated joint. Solder when it melts, flows toward heat. There-

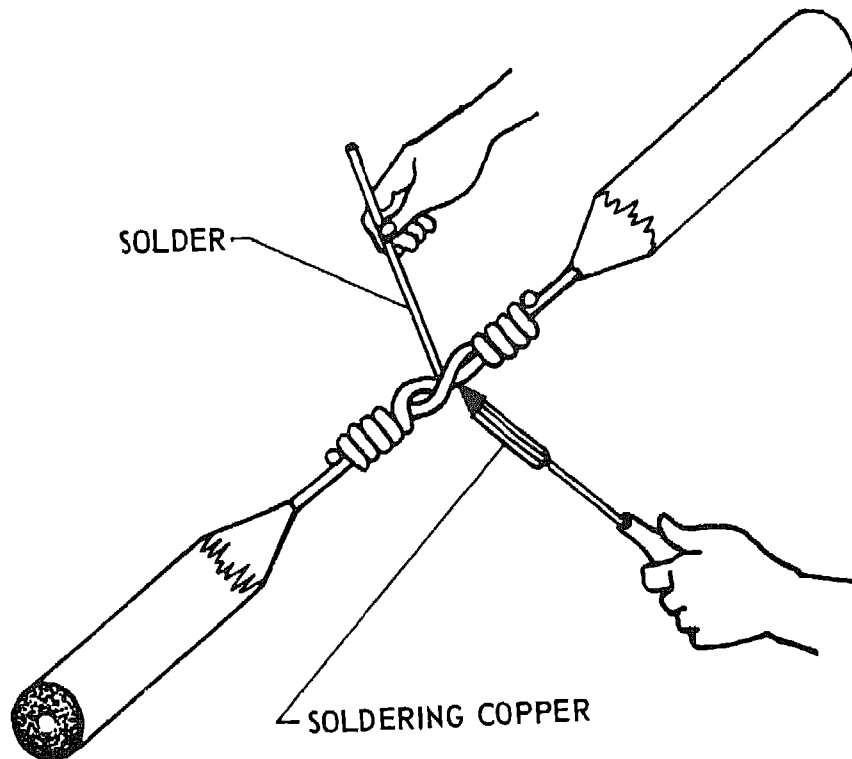


Fig. 4.3.B. Solder Flows toward Heat

fore, it will melt and freely flow towards the soldering iron.

- (7) Move the soldering iron and solder along the joint until the entire surface is covered. Apply only enough solder to flow freely and cover the surface completely. Never leave excess solder, rough solder, or chunks of solder on the work.

4.4 Tape

Tape is used to cover electric wires whenever additional insulation is needed. Normally it is used to recover damaged insulation, or to insulate bare wire connections that have been joined together. The tapes most commonly used for electricity are made of fabric, rubber, or plastic. The tapes, to make them adhere, and be resistant to moisture, heat and insects, have been treated with special insulation and adhesive compound. The average width of electricians tape is usually $\frac{3}{4}$ inch. The roll, wrapped tightly on a cardboard form, as shown in Figure 4.4 A, is approximately 3 inches in diameter. The tape, to help preserve the shelf life (Storage time before use) of the adhesive compound, should be encased in a moisture resistant wrapper.

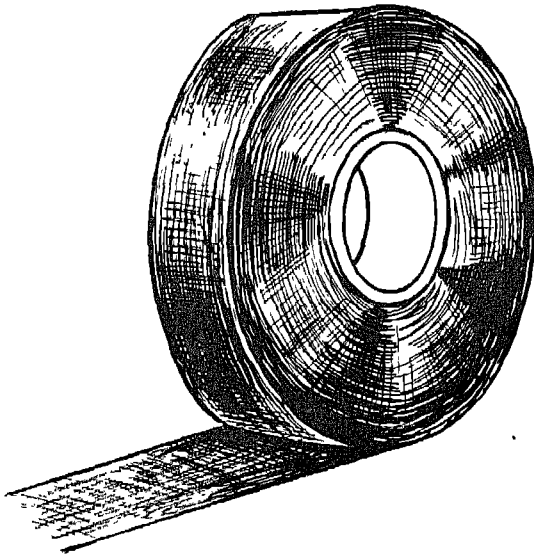


Fig. 4.4.A. Tape

Friction Tape—Friction tape is considered to be an all-purpose tape. It is made from a good quality of cotton and filled with a sticky rubber adhesive compound.

Rubber Tape—Rubber tape is made from pure rubber and is coated with a sticky rubber adhesive compound. It is an excellent insulating tape because it stretches as it is wrapped and conforms to the shape of the wire.

Plastic Tape—Plastic tape is made from a stretchable plastic and is coated with a sticky rubber adhesive compound. It is an excellent insulating tape because it stretches as it is wrapped and conforms to the shape of the wire.

Tape when properly applied should be wrapped around the bare wire, as shown in Figure 4.4 B, until it builds up to the thickness of the insulation of the wire. Then it should be extended in both directions to form a tight seal over the insulation of the wire.

5. ELECTRIC ACCESSORIES

5.1 Wall Sockets

Wall sockets, as shown in Figure 5.1.A, are manufactured for both light and power circuits. The light wall sockets are rated at 5 amperes—250 volts. The power wall sockets are rated at 15 amperes—250 volts. All wall sockets are similar in design and the procedure for mounting and wiring are about the same.

To wire a wall socket unscrew the bolt in the center of the top, as shown in Figure 5.1.B, and lift off the cover. The female receptacles should be adjusted to enable a two pin or three pin light plug to be easily pushed in and pulled out without sticking. Each female receptacle should have an internal bevel reamed in the end of the receptacle to better receive the two pin or three pin light plug. For a wall socket that receives a two pin light plug, strip approximately $\frac{1}{4}$ " of insulation from the flexible wires. For a wall socket that receives a three pin light plug, strip approximately $\frac{1}{2}$ " of insulation from the flexible wires. Be careful not to cut any strands in the flexible wire. Each strand removed

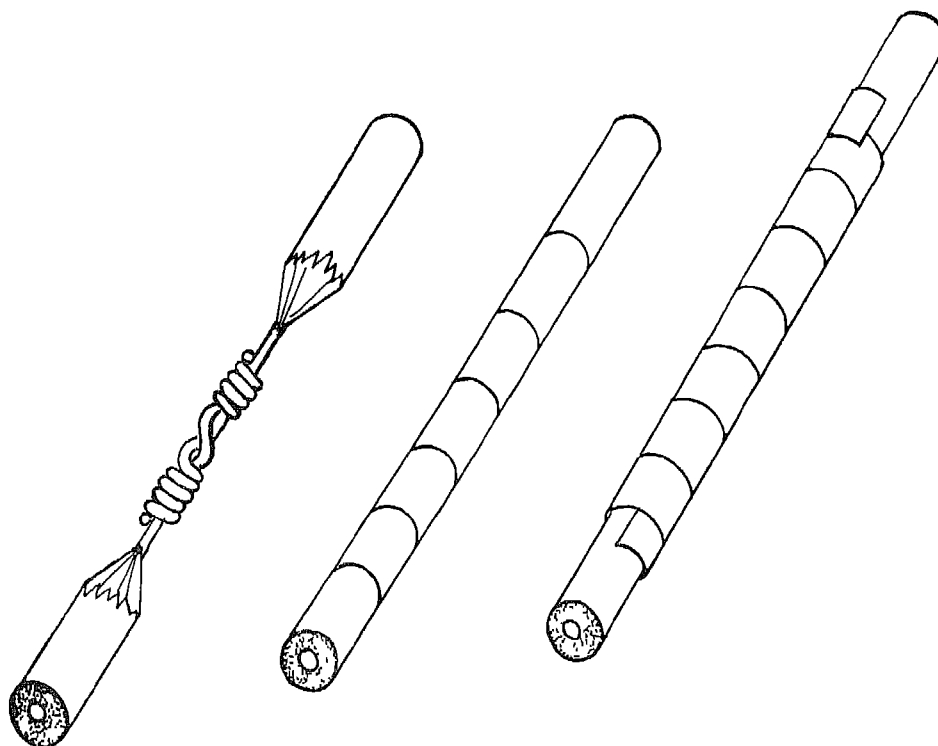


Fig. 4.4.B. Wire Connection Covered with Tape

actually decreases the size of the wire and reduces the rated electrical carrying capacity of the wire. Twist the strands of the bared ends of the flexible wire together. Slip each wire, from the bottom side, into the hole in the terminal post and tighten the set screw securely. When wiring a three pin wall socket *be sure* (looking from the top) to connect the LIVE wire (coloured black) to the right terminal post and the neutral wire (coloured red) to the left terminal post. The largest terminal post is for the earthing wire connection. These terminal posts usually are not marked. However, it is a good electrical practice to connect them correctly to the matching marked terminal posts of the three pin plug. Mount the base of the wall socket, with wood screws, on the round wood block fastened to the wall. Place the cover on the wall socket, insert the bolt and tighten it secu-

rely. Be sure that the holes in the cover line up accurately with the female receptacles.

5.2 Multiple Power Plug

The three pin multiple power plug, as shown in Figure 5-2. A, is designed to permit the use of several electrical appliances from one wall socket. All types of power plugs for average house use are usually rated at 15 amperes—250 volts. To inspect the interior of the multiple plug, as shown in Fig. 5.2.B, remove the bolt from the inside of the brass female earthing receptacle and carefully lift off the plastic cover. The five female receptacles on the angled end should be adjusted to enable a two pin and three pin light plug to be easily pushed in and pulled out without sticking. The ends of the female receptacles should be flared out enough to permit easy entrance of the two pin and three pin

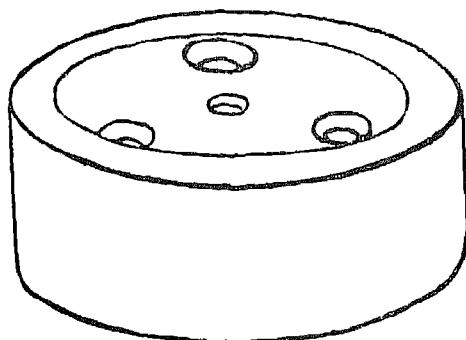


Fig. 5.1.A. Wall Socket

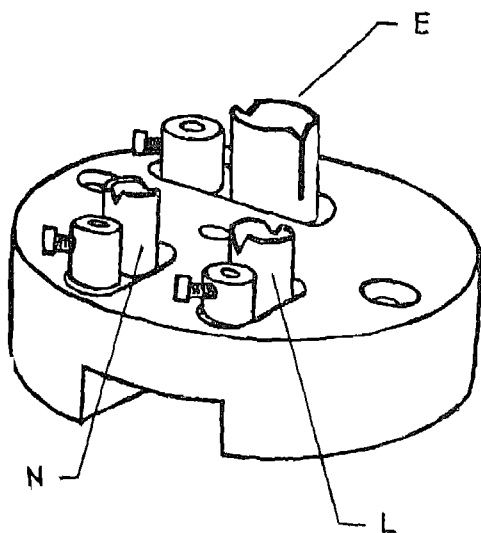
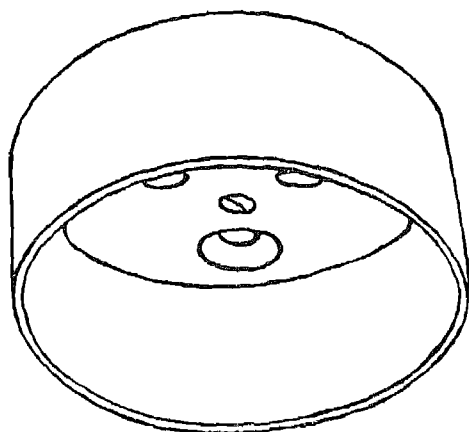


Fig. 5.1.B. Wall Socket Disassembled

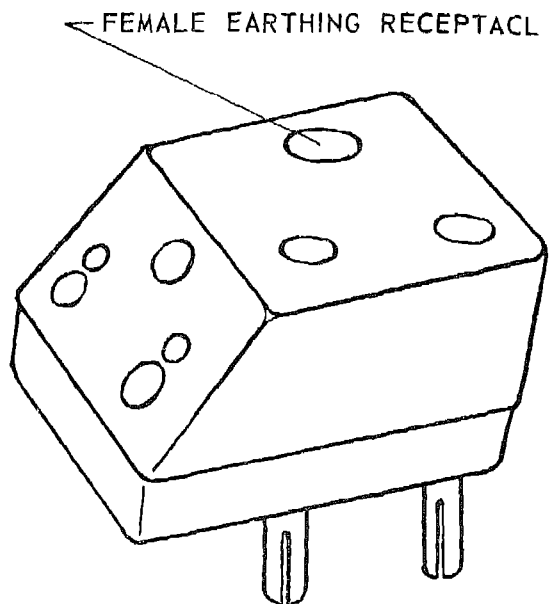


Fig. 5.2 A. Multiple Power Plug

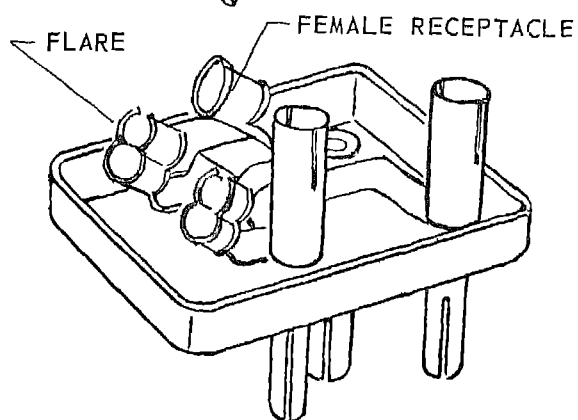
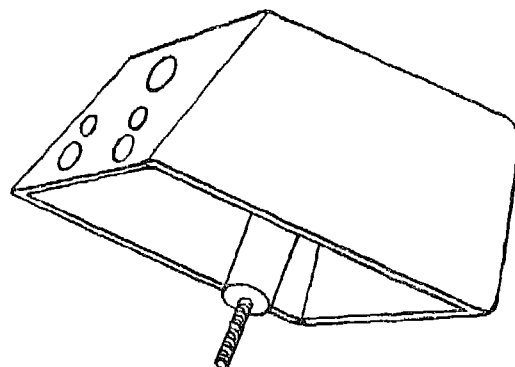


Fig. 5.2.B. Multiple Power Plug Disassembled

light plugs. Properly align all of the female receptacles in front of their respective holes in the plastic cover by bending them into position. When all of the female receptacles are in proper position, fasten them securely by tightening the two pin connectors that hold them to the base. Providing all the parts connected to the base are in proper alignment, the top plastic cover should slip easily into position. Fasten the cover securely to the base with the bolt from the inside of the brass female earthing receptacle. Check the end of the multiple plug to make sure the female receptacles are correctly lined up with the holes in the plastic cover. If they need adjustment push them into position with a small pointed tool.

5.3 Multiple Light Plug

The three pin multiple light plug, as shown in Figure 5.3. A, is designed to permit the use of

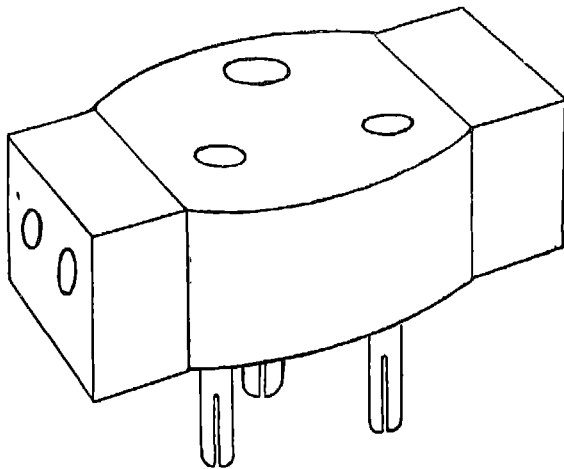


Fig. 5.3.A. Multiple Light Plug

several electrical appliances from one wall socket. All types of *light* plugs are usually rated at 5 amperes—250 volts. To inspect the interior of the multiple plug, as shown in Figure 5.3.B, remove the two bolts from the base and carefully lift off the plastic cover. The large earthing wire terminal should be covered with a piece of plastic tubing to prevent a short circuit. The two female receptacles on each end should be adjusted to

enable a two pin light plug to be easily pushed in and pulled out without sticking. The ends of the female receptacles should be flared out enough to catch behind the grooves in the plastic cover. When the female receptacles are properly fitted into the plastic grooves, they should remain in that position whenever a two pin plug is pushed in or pulled out. When the female receptacles are in proper position, fasten them securely by tightening the two pin connectors that hold them to the base. Providing all of the parts connected to the base are in proper alignment, the plastic cover should slip easily into position. Fasten the cover securely to the base with the two bolts. Check the ends of the multiple plug to make sure the female receptacles are correctly lined up with the holes in the plastic cover. If they need adjustment push them into position with a small pointed tool.

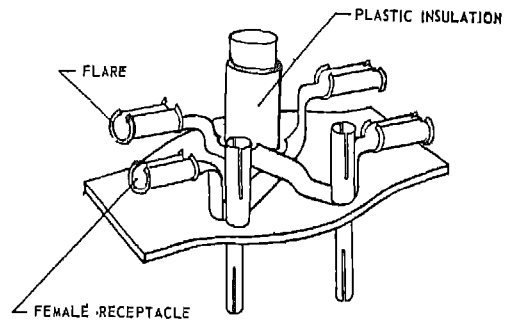
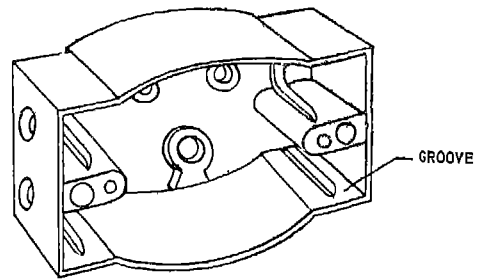


Fig. 5.3.B. Multiple Light Plug Disassembled

5.4 Two Pin Plug Top

Two pin plug tops, as shown in Figure 5.4-A, and 5.4 D, are manufactured in a variety of shapes

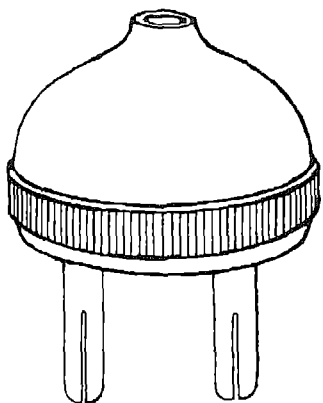


Fig 5.4.A. Two Pin Plug Top with Screw Cover

by different manufacturers. The best shape is one that can be grasped firmly in the hand and pulled out of a wall socket. *NEVER* remove any type of an attachment plug from a wall socket by pulling directly on the wires.

To wire the plug with the cover that unscrews, as shown in Figure 5.4.B, strip approximately 1/4" of insulation from each flexible wire. Be careful not to cut any strands in the flexible wire. Each strand removed actually decreases the size of the wire and reduces the rated electrical carrying capacity of the wire. Slip the flexible wire through the hole in the cover of the two pin plug. Tie an *Underwriters' knot**, as shown in Figure 5.4 C, in the two electric wires. The Underwriters' knot prevents the wires from being pulled unintentionally at the terminal posts. Check to see that the holes in the terminal posts are properly aligned

1. Underwriters' knot is an American term from the National Electric Code. The purpose of the code is to protect persons and buildings and their contents from electrical hazards. The National Electric Code is the standard of the National Board of Fire Underwriters and is approved by the American Standards Association. These two organizations, the same as the Indian Standards Institution, help to determine minimum safety standards for electric wiring and equipment.

and fastened securely in position, by tightening the two pin connectors that hold them to the base. Twist the strands of the bared ends of the wire tightly together. Place the ends of the wires in the terminal posts of the two pin plug and tighten the clamping screws securely. Screw the cover and base of the two pin plug together.

To wire the plug with the round style cover that is held on by a bolt that goes up through the base internally into the top, as shown in Figure 5.4 E, strip approximately 5/8" of insulation from

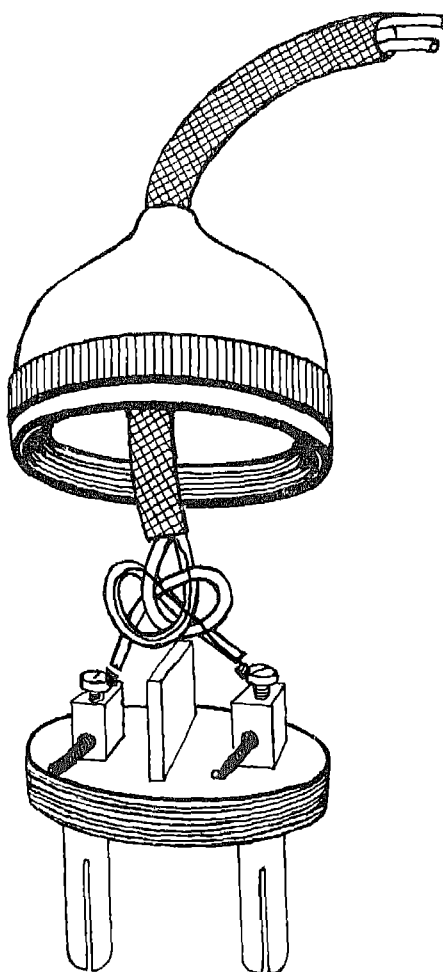


Fig. 5.4.B. Two Pin Plug Top with Screw Cover Disassembled

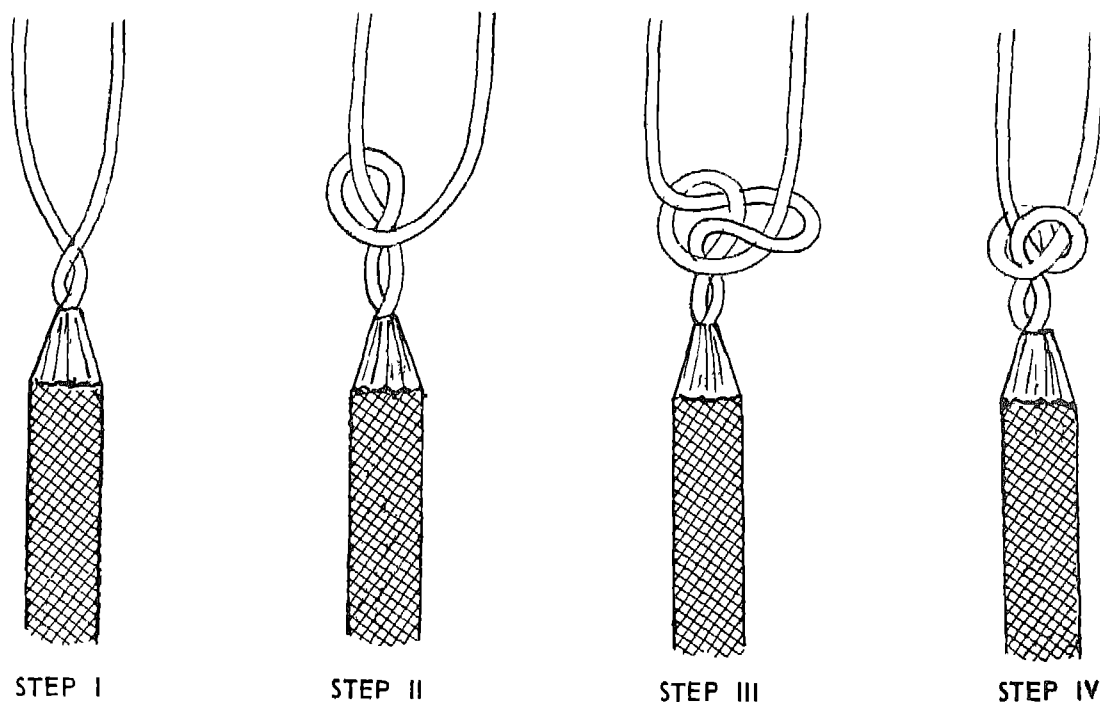


Fig. 5.4.C. Underwriters' Knot

each flexible wire. Twist the strands of the bared ends of the wire tightly together. A wire, for a good electrical connection, should always be looped around a bolt in the direction of tightening. Loop the wire completely around the body of the bolt and tighten the screw securely. A good electrical practice to follow, to prevent the wires from being pulled unintentionally at the terminal posts, is to loop each wire so that it will go around the center post when the plug is assembled. Place the cover on the plug, insert the bolt and tighten it securely.

5.5 Three Pin Plug Top

Three pin plug tops, as shown in Figure 5.5.A, and 5.5.C, are manufactured in a variety of shapes by different manufacturers. Some are designed for use with light gauge wire and others for heavy gauge wire. Select the plug with the best type of wire attachment, for any given size wire, that will prevent the wires from being pulled unintentionally at the terminal posts. It should also be

noted that many three pin plugs have the letters L, N and E printed clearly on the base beside each terminal post. The letter L signifies that it represents the live terminal post. The letter N signifies that it represents the neutral terminal post. The letter E signifies it represents the earthing terminal post.

The *round style plug* with the cover that is held on by a bolt that goes up through the base internally into the top, as shown in Figure 5.5.B, is usually used with light gauge wire. Strip approximately 1 1/4" of sheathing from the three wire electric cord and 1/4" of insulation from each flexible wire. Check to see that the holes in the terminal posts are properly aligned and fastened securely in position, by tightening the three pin connectors that hold them to the base. Twist the strands of the bared ends of the flexible wire tightly together. Place the ends of the wires in the terminal posts, according to the proper colour code. Connect the live wire (coloured black) to the terminal post marked L. Connect the neutral

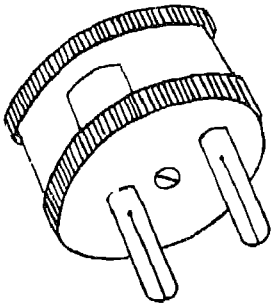


Fig. 5.4.D. Two Pin Plug Top with Round Style Cover

wire (coloured red) to the terminal post marked N. Connect the earthing wire (coloured green) to the terminal post marked E. Tighten the clamping screws securely. A good electrical practice to follow, to prevent the wires from being pulled unintentionally at the terminal posts, is to loop each wire so that it will go around the center post when the plug is assembled. Another good electrical practice to follow is to be sure that the cable sheathing is cut to the proper length, so that it remains inside the plug when it is assembled. Place the cover on the plug, insert the bolt and tighten it securely.

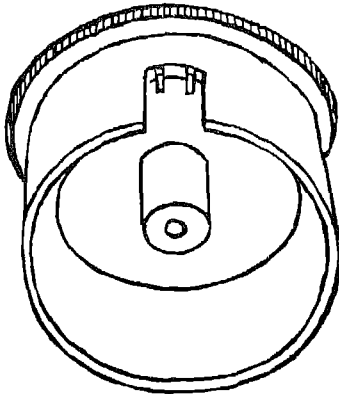


Fig. 5.4.E. Two Pin Plug Top with Round Style Cover Disassembled

The *oblong style plug*, with the cover that is held on by a bolt that goes up through the base internally into the top, as shown in Figure 5.5 D, is used with heavy gauge wire. Strip approximately 1 1/4" of sheathing from the three wire electric cord. Cut the live wire (coloured black) and the neutral wire (coloured red), where it extends from the sheathing, to approximately 3/4" in length. Strip approximately 1/2" of insulation from each of the flexible electric wires. Slip the electric cord through the plastic cord lock. Force each of the eye pins, by pushing up from the bottom, out of their lock-in position. Untwist the three

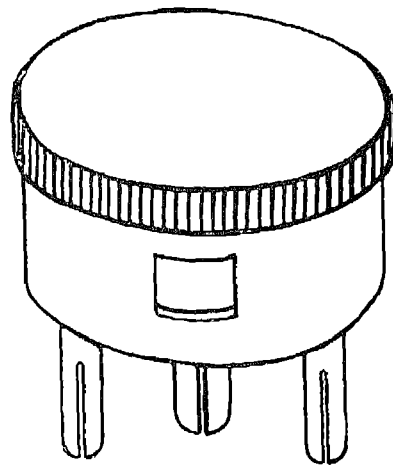


Fig. 5.5.A- Three Pin Plug Top with Round Style Cover

strands of wire so that the bared strands of wire are flat and parallel to each other. Place the ends of the bared wires in the eye pins, according to the proper colour code. Connect the live wire

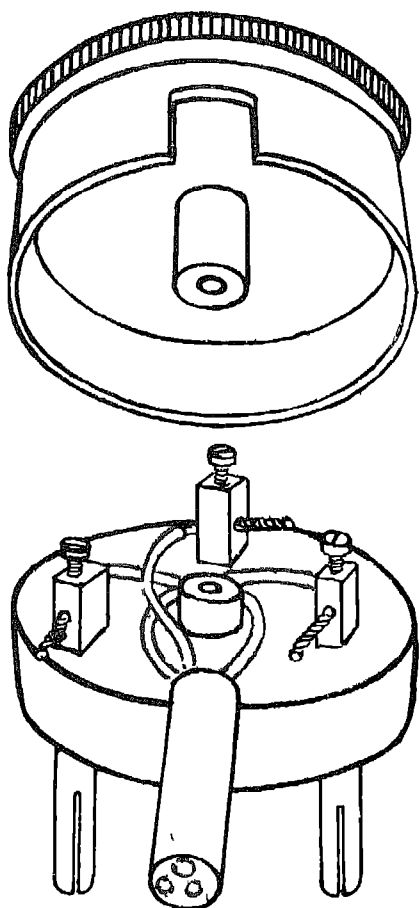


Fig. 5.5.B. Three Pin Plug Top with Round Style Cover Disassembled

(coloured black) to the lock-in pin marked L. Connect the neutral wire (coloured red) to the lock-in pin marked N. Connect the earthing wire (coloured green) to the lock in pin marked E. Force the eye pins and wires into their lock-in position. Slip the plastic cord lock, already on the electric cord, into its proper position. Place the cover on the plug, insert the bolt and tighten

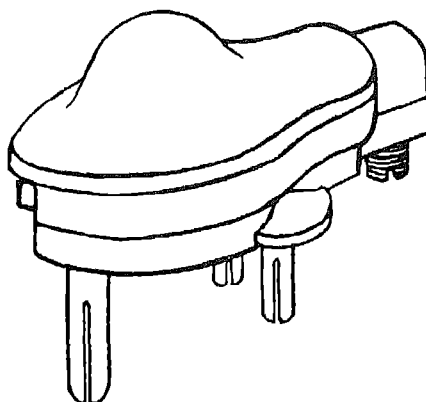


Fig. 5.5.C. Three Pin Plug Top with Oblong Style Cover

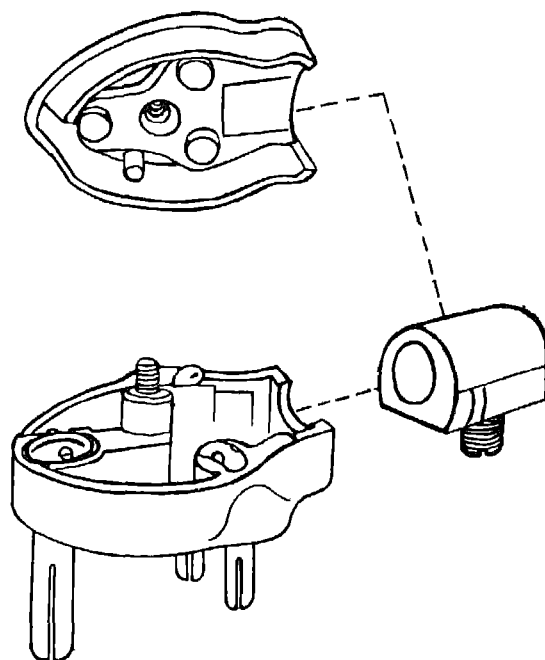


Fig 5.5.D. Three Pin Plug Top with Oblong Style Cover Disassembled

it securely. Twist the set screw in the cord lock snug against the electric cord. Providing that the electric cord fits the cord lock properly it should absorb all the strain and prevent the electric wires from being unintentionally pulled out of the lock-in pins.

5.6 Switch

Switches are important for controlling the use of electricity in a house. They permit electrical appliances to be turned on and off as they are needed. A switch is just like connecting or disconnecting a wire. Only, it is safer and faster, because, the opening and closing of the electric circuit is automatic and in an enclosed housing.

Switches, as shown in Figure 5.6 A, are

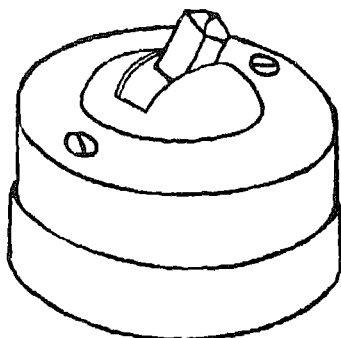


Fig 5.6.A. Switch

manufactured for both light and power circuits. The light switches are rated at 5 amperes—250 volts. The power switches are rated at 15 amperes—250 volts. All switches are similar in design and the procedure for mounting and wiring are about the same.

To wire a switch, as shown in Figure 5.6.B, unscrew the two bolts from the top and lift off the cover. For a light switch, strip approximately $1/4$ " of insulation from the flexible wire. For a power switch, strip approximately $1/2$ " of insulation from the flexible wire. Be careful not to cut any of the flexible wire strands. Each strand removed actually decreases the size of the wire and reduces the rated electrical carrying

capacity of the wire. Twist the strands of the bared ends of the flexible wire together. Slip each wire, from the bottom side, into the hole in the terminal post and tighten the set screw securely. Mount the base of the wall switch, with wood screws on the round wood block fastened to the wall. Place the cover on the wall switch, insert the two bolts and tighten them securely.

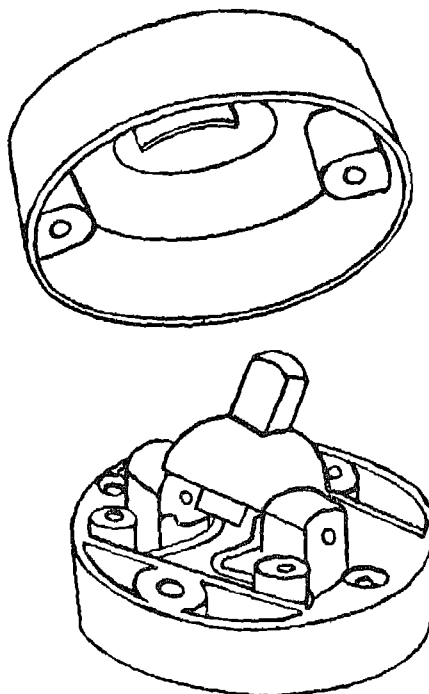
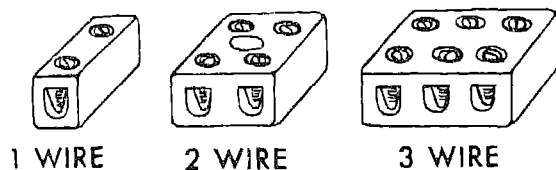


Fig. 5.6 B. Switch Disassembled

5.7 Porcelain Connector

Porcelain, a combination of quartz and clay, makes a good connector with unusual strength. It is used as a solderless connector, as shown in Figure 5.7.A, where two or more wires are to be connected together. Strip approximately $3/8$ " of insulation from each wire. Twist the strands of the bared ends of the wire tightly together. Insert the ends of each wire into a terminal post and tighten the clamping screws securely. The two wire connector has the advantage of being designed

with a mounting hole that permits it to be bolted or screwed rigidly into position.



5.7.A. Porcelain Connectors

5.8 Lamp Holder

Lamp holders of various types, as shown in Figures 5.8.A, and 5.8.C, are produced by different manufacturers. The most common types are designed to hold a bayonet base lamp bulb, be rigidly mounted on the wall, or hung from the ceiling.

The *fixed type lamp holder*, as shown in Figure 5.8.B, is designed to be rigidly mounted on the wall. Disassemble the fixed type lamp holder by :

- (1) Unscrewing the shade lock nut.
- (2) Unscrewing the lamp holder collar.
- (3) Removing the housing.
- (4) Removing the ceramic base unit.

Slip the base of the lamp holder over the electric wires protruding from the round wood block mounted on the wall. Mount the base of the lamp holder, with wood screws, on the round wood block. Check the two terminal posts for secure mounting by tightening the two bolts that hold them to the ceramic base. Strip approximately $\frac{1}{4}$ " of insulation from the flexible wire. Be careful not to cut any of the flexible wire strands. Each strand removed decreases the size of the wire and reduces the rated electrical carrying capacity of the wire. Twist the strands of the bared ends of the wire together. Slip each wire, from the bottom side of the ceramic unit into the hole in the terminal post and tighten the set screw securely. Reassemble the lamp holder by:

- (1) Placing the ceramic unit, with the indents aligned, in the base of the lamp holder.
- (2) Placing the housing, with the indents aligned, over the ceramic unit.
- (3) Placing the lamp holder collar over the housing and screwing it tightly to the base.
- (4) Placing the shade lock nut over the housing and screwing it into position.

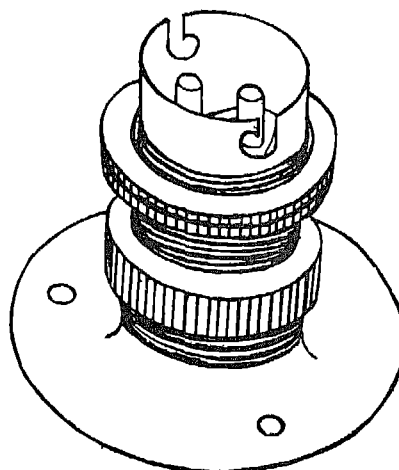


Fig. 5.8 A. Fixed Type Lamp Holder

The *Pendant type lamp holder* is designed to be suspended from the ceiling by the electric cord. Disassemble the pendant type lamp holder, as shown in Figure 5.8.D, by :

- (1) Unscrewing the shade lock nut.
- (2) Unscrewing the pendant cap.

Strip approximately $\frac{1}{4}$ " of insulation from the flexible wire. Be careful not to cut any of the flexible wire strands. Each strand removed actually decreases the size of the wire and reduces the rated electrical carrying capacity of the wire. Twist the strands of the bared ends of the wire together. Slip the pendant cap over the electric wires hanging from the ceiling. Slip each wire through the hole in the center divider. Place each wire in the hole in the terminal post and tighten

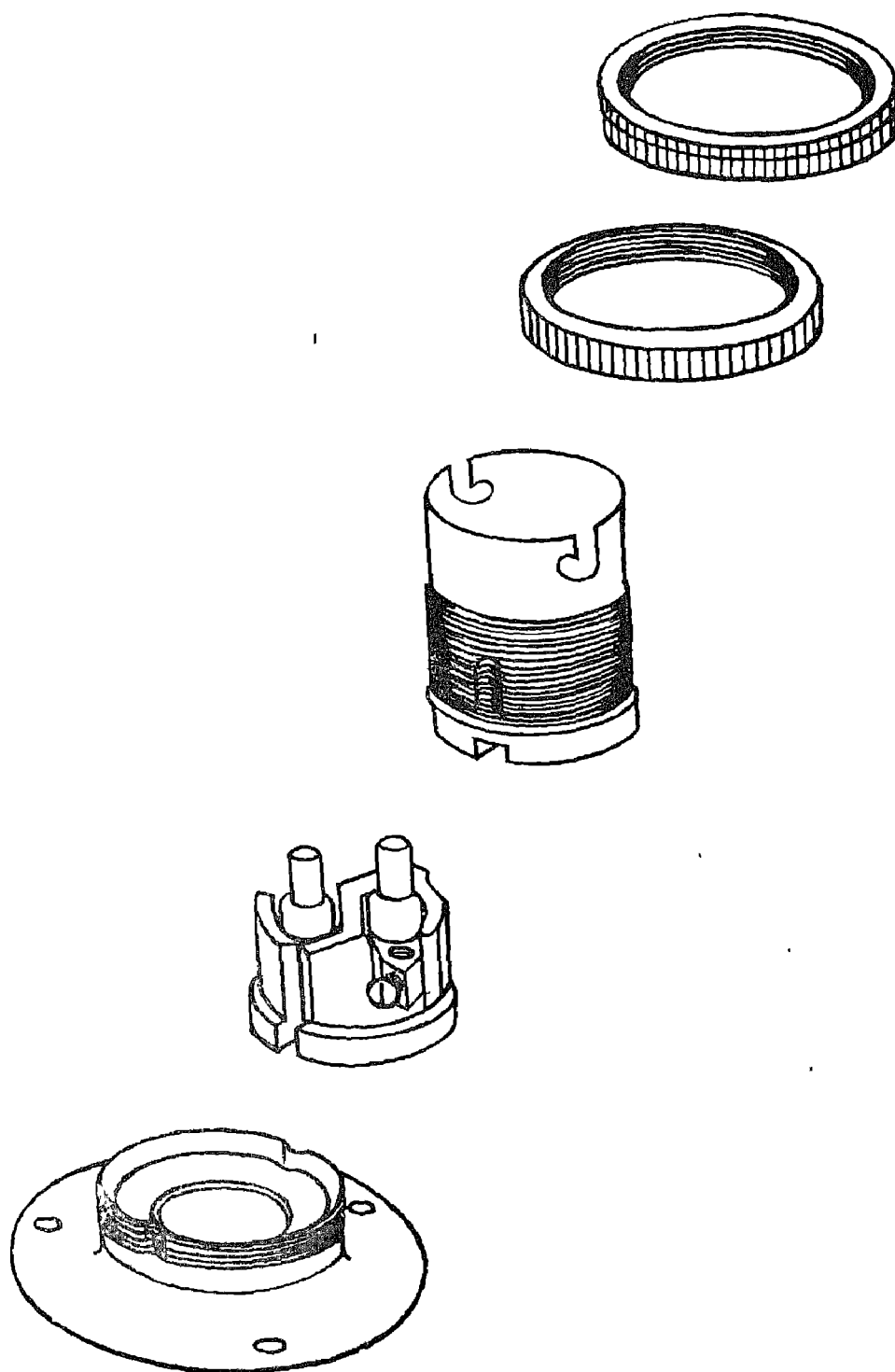


Fig. 5.8.B. Fixed Type Lamp Holder Disassembled

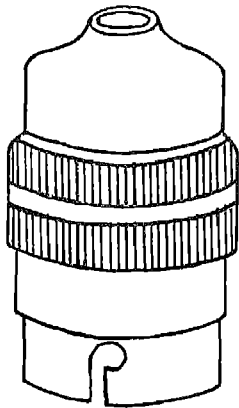


Fig. 5.8.C. Pendant Type Lamp Holder

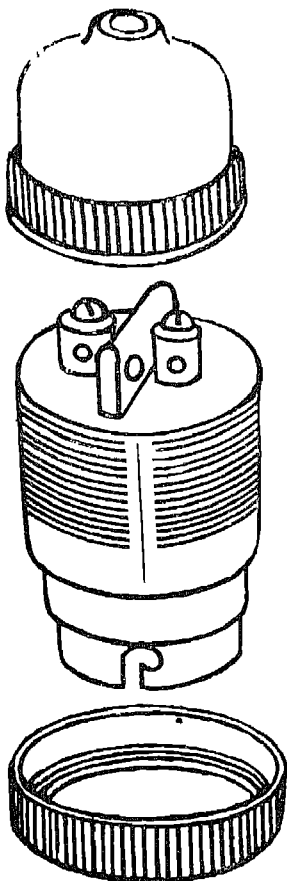


Fig. 5.8.D. Pendant Type Lamp Holder Disassembled

the set screw securely. The center divider with the holes prevents the wires from being pulled from the terminal posts while the pendant lamp is suspended from the ceiling. All pendant lamp holders should be provided with a mechanical holder of some type to prevent the wire from being pulled from the terminal posts. If no mechanical holder is provided, tie an Underwriters' knot, as shown in Figure 5.4.C, in the two electric wires. The Underwriters' knot will prevent the wires from being pulled at the terminal posts. Reassemble the pendant lamp holder by

- (1) Screwing the pendant cap on the holder housing
- (2) Placing the shade lock nut over the holder housing and screwing it into position.

5.9 Lamp

The modern *incandescent* lamp, as shown in Figure 5.9.A, has a *filament* made of tungsten wire. This type of tungsten wire will withstand very

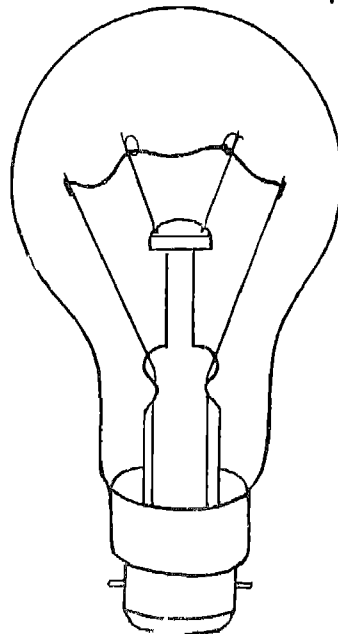


Fig. 5.9.A. Lamp

high temperatures and produce an incandescent or white-hot glow. The tungsten wires resistance to the flow of current enables the wire to become very hot and give off a white glow. When air is removed from the glass bulb, the tungsten wire glows but does not burn because the presence of air would support combustion. Also, a mixture of argon and nitrogen gas is placed inside the glass bulb. The gas lengthens the life and the light producing ability of the lamp. The lamps are manufactured with clear or frosted glass. Clear glass lamps are used in enclosing globes and for indirect lighting. The inside frosted glass lamps diffuse (spread out) and soften the light. Therefore, frosted lamps should always be used where they are directly exposed to the eyes. Incandescent lamps are usually manufactured in a variety of sizes and shapes. The most popular sizes for house use are 25, 40, 60, 100 and 150 watts. The most commonly used base is the bayonet type with two protruding pins. The lamp when pushed in and turned, is locked into the socket by the two pins. To remove the lamp push down on the glass bulb, and turn the lamp until the two pins come out of the socket slots.

5.10 Link Clip

Link clips are made of thin sheetmetal, as shown in Figure 5.10.A, which enables them to be bent very easily by hand. They are manufactured in three qualities :

- (1) Tinned sheet iron
- (2) Brass
- (3) Tinned brass

The tinned brass clip is the least affected by corrosion. The width of the link clip is usually about $1\frac{1}{2}$ " and the lengths are $1\frac{1}{4}$ ", $1\frac{1}{2}$ ", $1\frac{3}{4}$ ", 2", $2\frac{1}{4}$ ", $2\frac{1}{2}$ " and 3". The length of the link clip selected depends upon the size and the number of electric wires to be mounted. Usually for the electric wires that are mounted in the average house, the $1\frac{1}{2}$ " link clip is satisfactory. The link clips are easily nailed to the externally mounted wood batten, as shown in Figure 5.10 B, because they are made of thin metal. The link clips, for

the safest and most economical electrical wire mounting, should be spaced 4 inches apart. Link clips spaced too far apart permit the electric

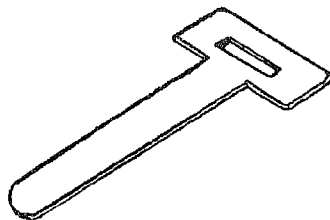


Fig. 5.10.A Link Clip

wires to sag. This is an unsafe and expensive electrical practice. Pull the electric wire taut, as each link clip is bent and fastened snugly around the wire.

5.11 Ceiling Rose

The ceiling rose, as shown in Figure 5.11.A, is used to hang a lamp from the ceiling. Disassemble the ceiling rose, as shown in Figure 5.11.B, by unscrewing the cap from the base. Strip approximately $1\frac{1}{2}$ " of insulation from the electric wires protruding from the round wood block fastened to the ceiling. Twist the strands of the bared ends of the wire together. Slip each wire, from the back side of the base unit, into the hole in the terminal post and tighten the set-screw securely. Mount the base of the ceiling rose, with wood screws, on the round wood block fastened to the ceiling. Strip approximately $3\frac{1}{4}$ " of insulation from the ends of the flexible electric wires that are to suspend the hanging lamp from the ceiling rose. Slip the bared ends of the flexible electric wires through the hole in the ceiling rose. Tie an Underwriters' knot, as shown in Figure 5.4.C, in the two electric wires. The Underwriters' knot will support the weight of the hanging lamp and prevent the wires from being pulled out of the terminal posts. Twist the strands of the bared ends of the flexible wire tightly together. Wrap the twisted end of each wire, in the direction of tightening, around the bolt screwed into the base of each terminal unit. Tighten the bolt securely. Assemble the ceiling rose by screwing the cap securely to the base.

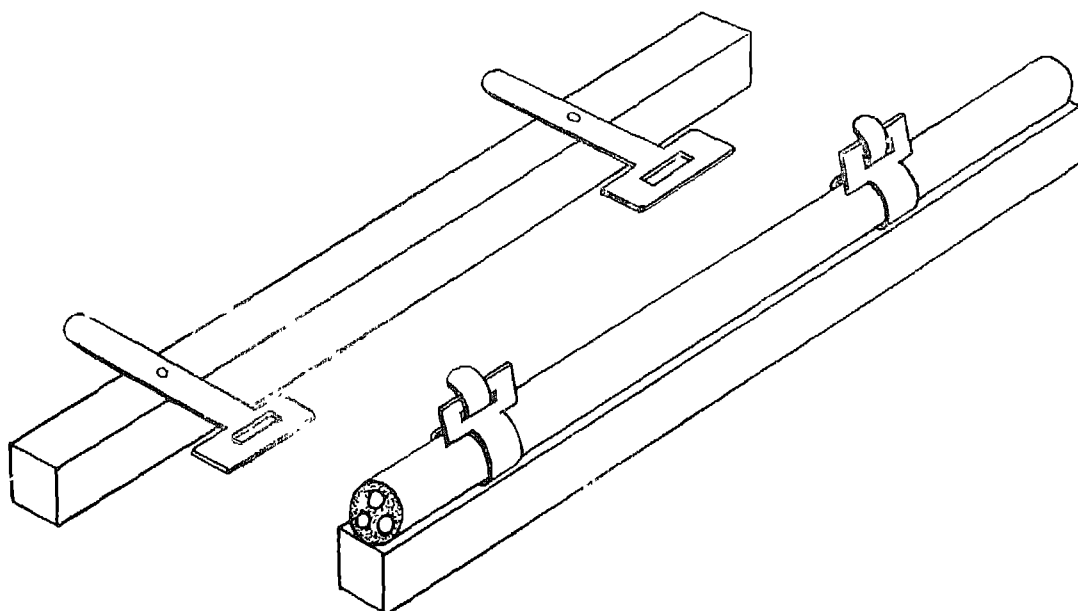


Fig. 5.10 B. Link Clip Mounting Procedure

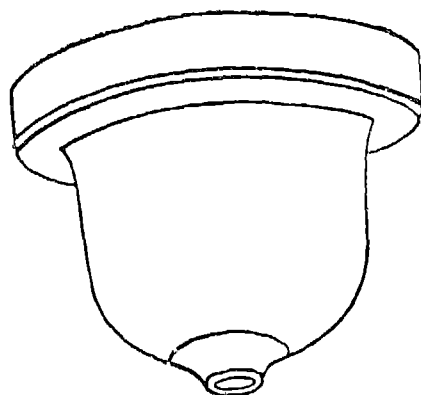


Fig. 5.11.A. Ceiling Rose

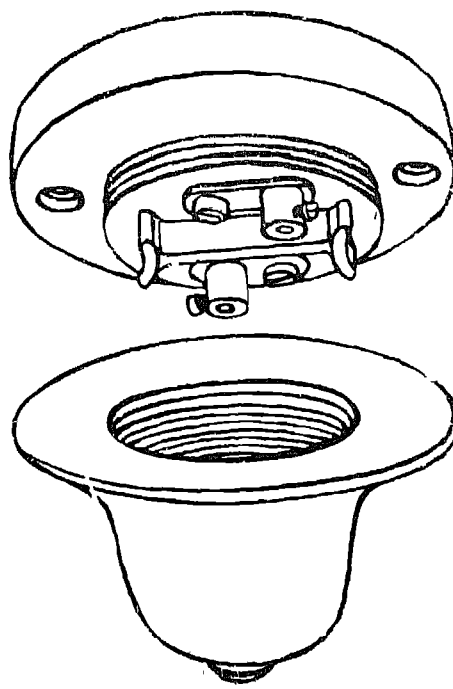


Fig. 5.11.B. Ceiling Rose Disassembled

5.12 Bell Push

The bell push, as shown in Figure 5.12.A, operates a bell or buzzer by making an electrical

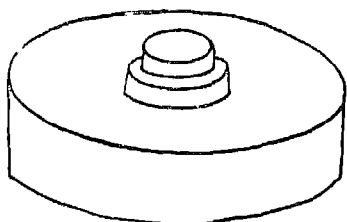


Fig. 5.12 A Bell Push

contact when the button is pushed. The push button is spring loaded so that the contact points are open when the button is out. A bell push is just like connecting or disconnecting a wire, or turning a switch on or off. In a sense, it is an automatic OFF switch that must be manually pushed into the ON position. Strip approximately 3/4" of insulation from the ends of the flexible electric wires that are protruding from the round wood block. Twist the strands of the bared ends of the flexible wire tightly together. Wrap the twisted ends of each wire, in the direction of tightening, around each terminal bolt on the back side of the bell push. Then tighten the bolts securely. Mount the bell push with wood screws on the round wood block.

5.13 Bell and Buzzer

The electric bell and buzzer are common household signalling devices. The bell is usually connected to the front door to announce the arrival of callers. The buzzer is usually connected to the back door or as a servant's signal to various rooms in the house. Both the bell and the buzzer operate on 230 volt—50 cycle alternating current. Bells and buzzers are also made that will operate on a low voltage system. However, to reduce the 230 volt system to approximately 10 volts a step-down transformer must be used. Both the bell and the buzzer work on the principle of magnetism. When the bell button is pushed the circuit

is closed and the coil becomes energized. The energized coil then operates as an electromagnet. (The principle of the electromagnet is explained in the unit on Electric Motors)

(Bell)

The bell, as shown in Figure 5.13.A, is usually

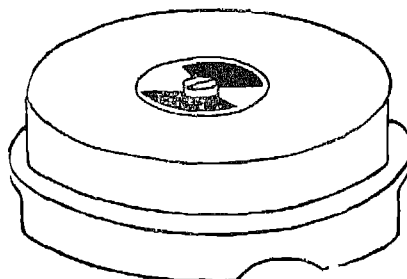


Fig. 5.13.A Bell

round in shape. The bell cover, as shown in Figure 5.13 B, is removed by unscrewing the bolt that goes through the top and fastens internally into the base. The electromagnet which becomes energized and de-energized momentarily, as the alternating current changes direction, attracts the spring loaded clanger. The clanger, as it is attracted by the pulsating electromagnet and mechanically disengaged by the spring tension action, vibrates forth and back. The clanger striking the bell cover, sets up the sound waves that we hear when the bell rings. (The principle of sound waves is described in the unit on the Crystal Radio).

Slip the base of the bell over the electric wires protruding from the round wood block mounted on the wall. Each flexible electric wire should enter the base through one of the large holes on each side of the clanger. Mount the base of the bell rigidly with wood screws, on the round wood block. Or, hang the bell from a single screw in the slotted screw hole provided at the far end of the magnetic coil. The bell to

operate efficiently, and take advantage of the principle of gravity, *must* be hung with the clanger at the bottom. Strip approximately 1/4"

back and forth against the metal core of the electromagnet. The loudness or softness of the buzzer sound depends upon the size of the air gap between the spring loaded contact and the core of the electromagnet, the spring tension of the spring loaded contact, and the strength of the electromagnetic coil. The mounting procedure for the buzzer is exactly the same as the bell.

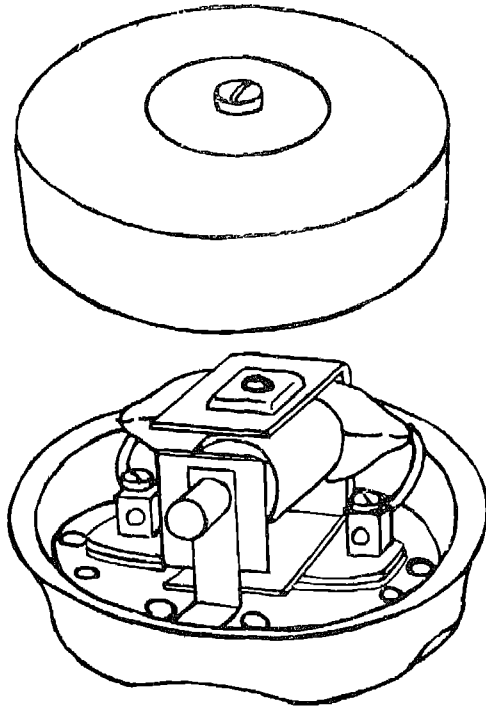


Fig. 5.13.B. Bell Disassembled

of insulation from the flexible wire. Twist the strands of the bared ends of the wire together. Slip each wire into the hole in the terminal post and tighten the set screw securely. Place the bell cover into position, insert the bolt and tighten securely

(Buzzer)

The (buzzer), as shown in Figure 5.13.C, is usually square in shape. The cover, as shown in Figure 5.13 D, is removed by unscrewing the bolt that goes through the top and fastens internally into the base. The buzzer operates on the same electric principle as the bell. However, there is no clanger to make the ringing sound of a bell. Instead, one hears the rapid vibration chatter of the spring loaded contact, vibrating

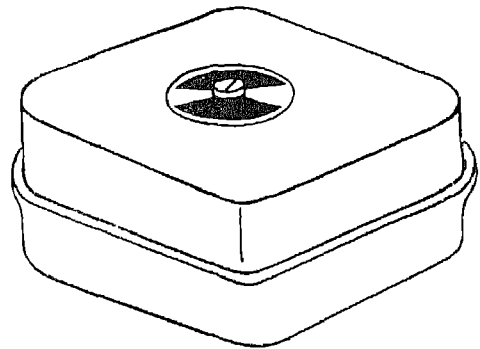
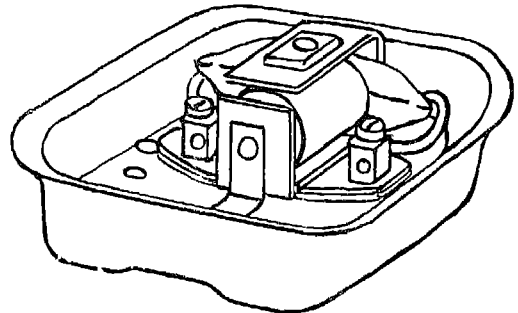
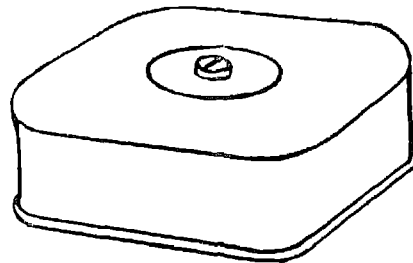


Fig 5 13.C. Buzzer



Be sure to hang the buzzer, because of the advantage of gravity with the spring loaded contact at the bottom.

6. ELECTRIC WOODEN GOODS

Various types of wood fittings are made to safely fasten wire and electrical accessories externally on a masonry wall. The most commonly used wood fittings are gutties, wood battens, casing and capping, wood boards and round wood blocks.

6.1 Gutties

Gutties, as shown in Figure 6.1.A, are wood

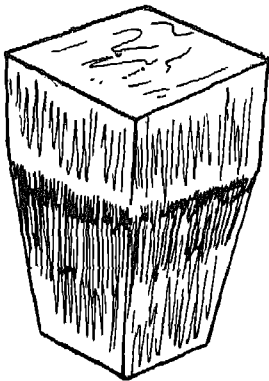


Fig. 6.1.A Gutti

plugs used to mount various types of fittings securely to a masonry wall. They are usually made from teak wood or some other hardwood. The shape of the gutti is almost always square. The top third of the gutti has straight sides, while the bottom two thirds of the gutti has a slight taper. A gutti, as shown in Figure 6.1.B, is securely fastened into a masonry wall by :

- (1) Chiseling a hole slightly larger than the gutti, with an inside taper (the inside measurement of the hole is larger than the outside), into the masonry
- (2) Filling the hole with fresh mixed cement,

- (3) Driving the gutti into the hole, large end first, until it is $1/4$ " below the surface of the masonry.
- (4) Smoothing off the cement flush with the masonry surface. A gutti, to take full mechanical advantage of the tapered hole in the masonry and the tapered shape of the gutti, should be inserted with the large end in. When the cement hardens the tapered gutti cannot be pulled out, because the large end will not fit through the smaller surface hole.

6.2 Wood Batten

The wood batten is a rough construction type, but least expensive external mounting. It is usually made from teak wood or some other hardwood.

The batten used in the average house, as shown in Figure 6.2.A, is approximately $1/2$ " thick and $1/2$ ", $3/4$ ", or $1 1/4$ " in width. The batten to be securely mounted should be fastened to the masonry with wood plugs (gutties) and flathead screws. The flathead screws, for rigid mounting, should be spaced approximately two feet apart.

6.3 Casing and Capping

Casing and capping, although externally mounted on the masonry wall, completely enclose the electric wires from view. The casing and capping are usually made from teak wood or some other hardwood. The casing, as shown in Figure 6.3.A, is grooved to hold the wires. The number of grooves and sizes of the grooves varies according to the number and sizes of the wires to be enclosed. The casing to be securely mounted should be fastened to the masonry with wood plugs (gutties) and flathead screws. The flathead screws, for rigid mounting, should be spaced approximately two feet apart. The electric wires are placed in the grooves of the casing. The capping which also has matching grooves, is placed in position over the electric wires in the casing. The capping should be screwed to the

casing with roundhead brass screws spaced 12" apart on alternate sides of the casing. Care must be taken, in the alignment of the screws to insure that the screws do not come in contact with the electric wires.

6.4 Wood Board

Wood boards, as shown in Figure 6.4.A, are used on masonry walls for external mounting of switches and wall sockets. The wood boards are usually made from teak wood or some other hardwood. The wood boards, from underneath, appear to be constructed like a shallow box. This permits the electric wires to be drawn

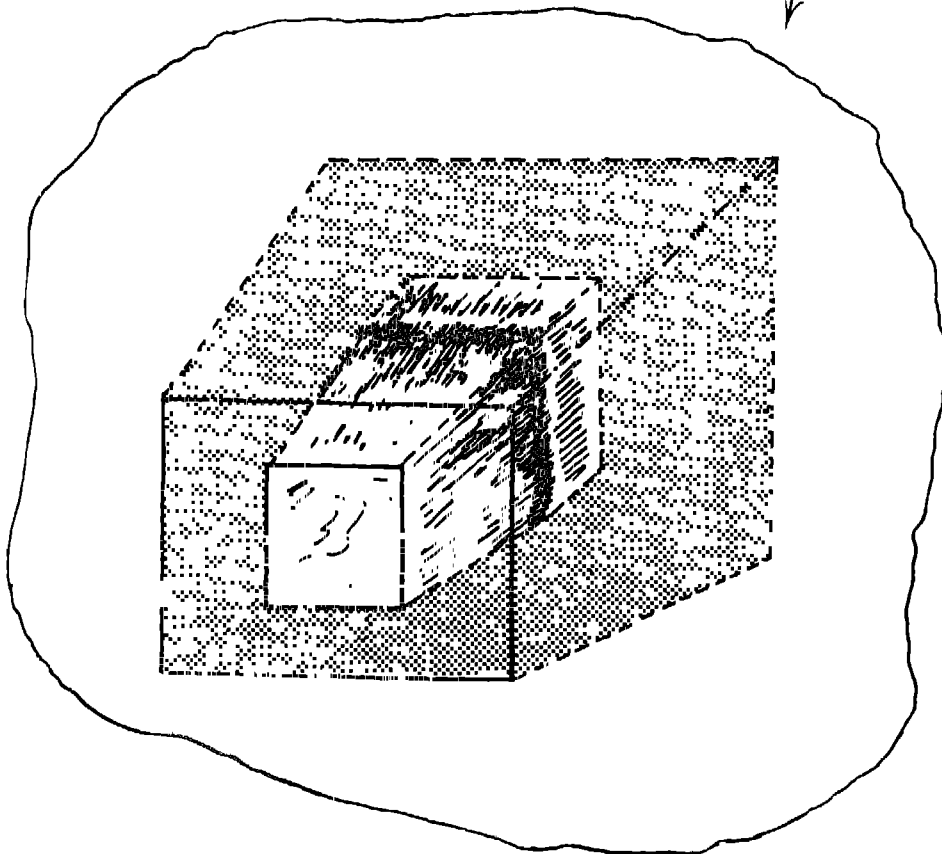


Fig 6.1.B. Gutti Securely Fastened in a Masonry Wall

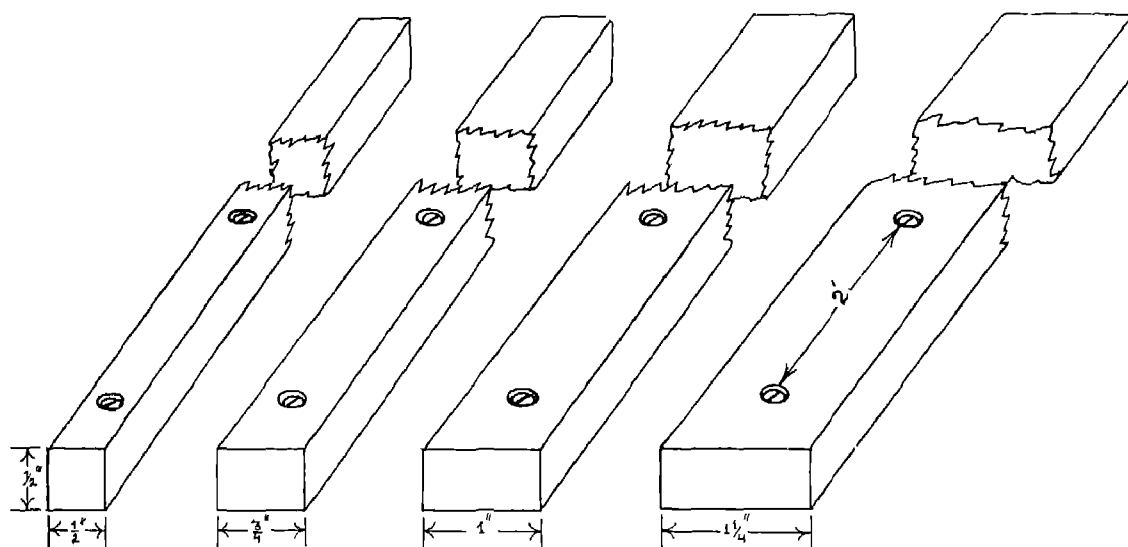


Fig. 6.2.A. Wood Battens

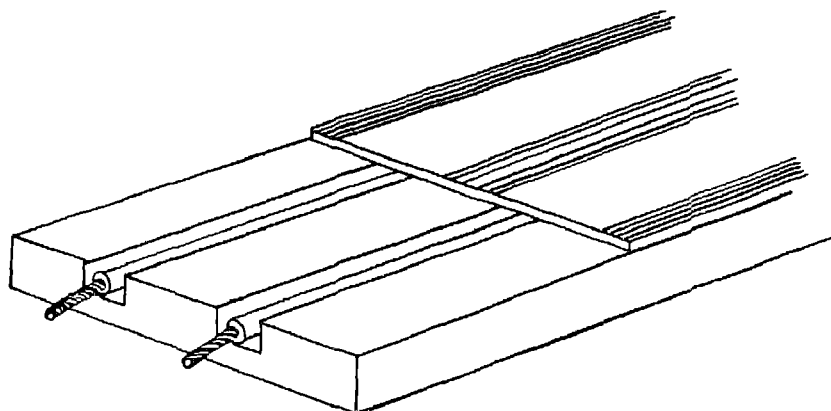


Fig. 6.3.A. Casing and Capping

through holes that can be bored through the sides and top of the wood board. The switches and wall sockets can then be correctly and safely mounted with internal electrical connections. The wood boards are made in a variety of sizes from small to large. However, the most common sizes used for mounting switches and wall sockets in a house are 4"x7", 9" x 15", 12" x 18". The wood board, to be securely mounted, should be fastened to the masonry with at least two wood plugs (gutties) and flathead screws.

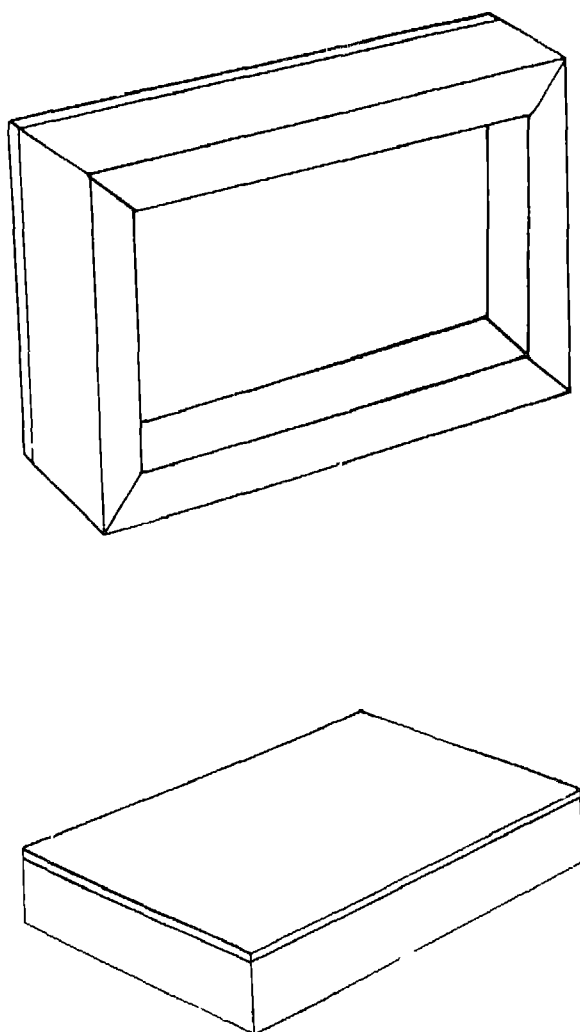


Fig 6.4.A. Wood Board

6.5 Round Wood-block

Round wood-blocks, as shown in Figure 6-5.A, are used, on masonry walls, for external mounting of individual lights, switches or wall sockets. The round wood-blocks are usually made from teak wood or some other hardwood. The round wood-blocks, made from one solid piece of wood, are hollow underneath. This permits the electric wires to be drawn through holes that can be bored through the side and top of the round wood-block. The light, switch or wall socket can then be correctly and safely mounted with internal electrical connections. The round wood-blocks are made 3", 3 1/2", and 4" in diameter and 1 1/2" in thickness. The average size used, for mounting lights, switches and wall sockets in a house, is the 3" x 1" round wood-block. The round wood-blocks, to be securely mounted, should be fastened to the masonry with at least two wood plugs (gutties) and flathead screws.

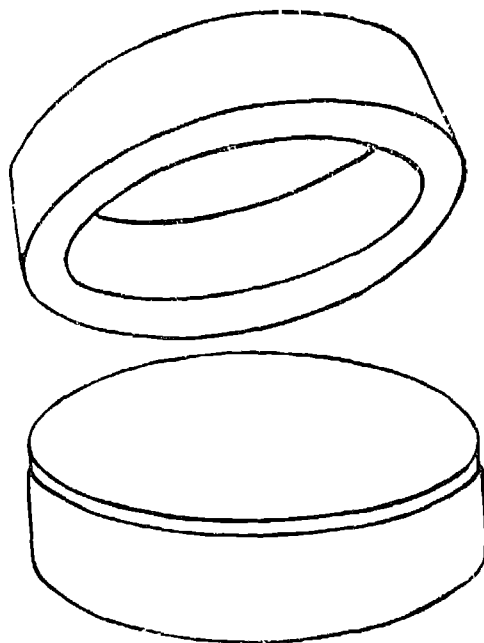


Fig. 6.5.A. Round Wood Block

7. ELECTRIC METERS

7.1 Meter Movement

Electrical quantities such as voltage, current and resistance can be accurately measured with instruments called *meters*. Although we cannot see electricity, the meter is designed to react to these electrical quantities, and we can read the electrical reaction on the meters calibrated scale. The mechanical movement in an electrical measuring device, as shown in Figure 7.1.A, consists of a fixed permanent magnet and a movable coil. The strength of the fixed permanent magnet remains constant. The strength of the moving coil field is dependent upon the amount of current

flowing through the coil. Therefore, when the *test prods* are touched to an electrical source, current passes through the coil. The energized coil becomes an electromagnet (Electromagnetism is described in the unit on Electric Motors). The poles of the electromagnet are attracted and repelled by the poles of the permanent magnet. The amount of the coils rotation, on its pivot point, is dependent upon the strength of the magnetic field generated. Any amount of rotation of the coil will be reflected by the movement of the pointer across the scale.

The voltmeter, ammeter and ohmmeter are the three most widely used meters. These meters can be purchased separately in a variety of styles and sizes. The newest type of meter available,

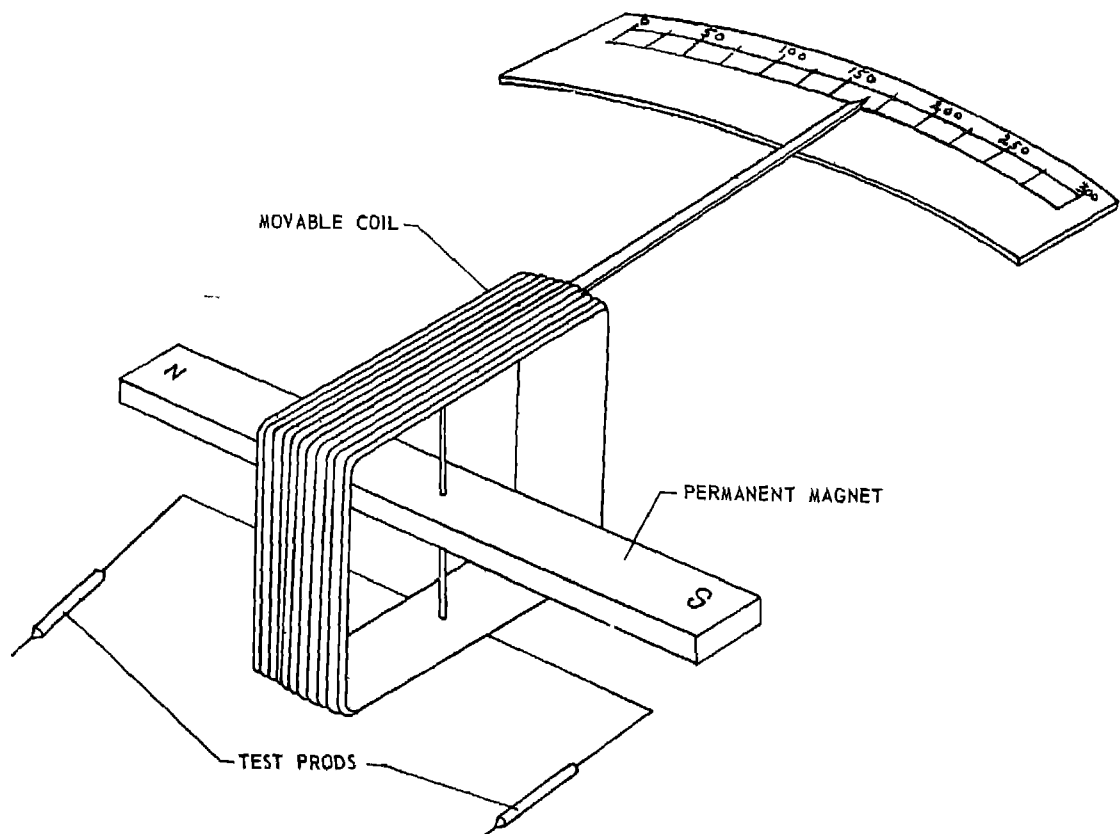


Fig. 7.1.A. Electric Meter Mechanical Movement

called the multimeter, is a combination of voltmeter, ammeter and ohmmeter. All electric measuring meters are very delicate instruments. They must be used correctly and with extreme caution. The improper use of an electric meter, even though only momentarily, can cause severe damage to the meter.

7.2 Voltmeter

The voltmeter is used to measure volts. One type of voltmeter is designed to measure direct current (DC). Another type of voltmeter is designed to measure alternating current (AC). The direct current voltmeter is a polarized instrument. To operate this meter the test prods of the positive meter terminal must be connected to the positive side of the circuit; and the test prod of the negative meter terminal must be connected to the negative side of the circuit. The test prods of the alternating current voltmeter, because it is designed to read alternating current, can be connected to either side of an alternating current circuit. A voltmeter is properly connected, as

shown in Figure 7.2.A, across the two wires of a circuit. Notice that this implies the voltage can also be checked at the fan or light bulb, as long as the voltmeter is connected across the two wires of the circuit.

Four important precautions should be followed to protect the voltmeter from damage.

- (1) Select the correct voltmeter for a direct current or alternating current circuit.
- (2) Be sure, the voltmeter has a high enough reading scale to measure the voltage in the circuit.
- (3) Be sure, with a direct current circuit, to connect the positive and negative meter terminals to the correct side of the circuit.
- (4) Be sure to always connect the voltmeter across the circuit.

7.3 Ammeter

The ammeter is used to measure current. One type of ammeter is designed to measure direct current (DC). Another type of ammeter is

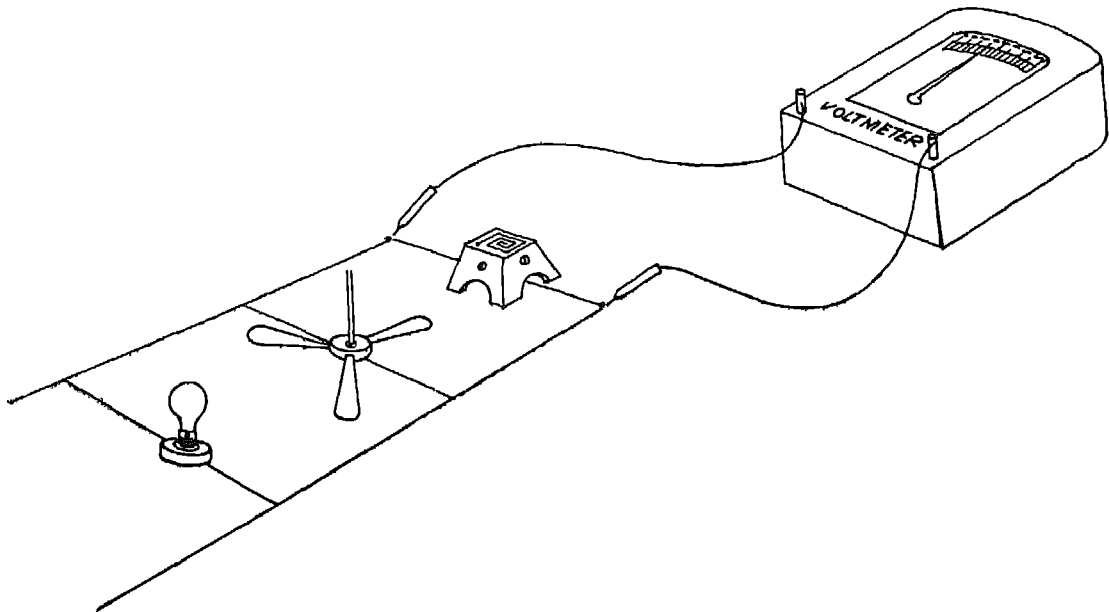


Fig. 7.2.A, The Voltmeter is Connected across Two Wires of a Circuit

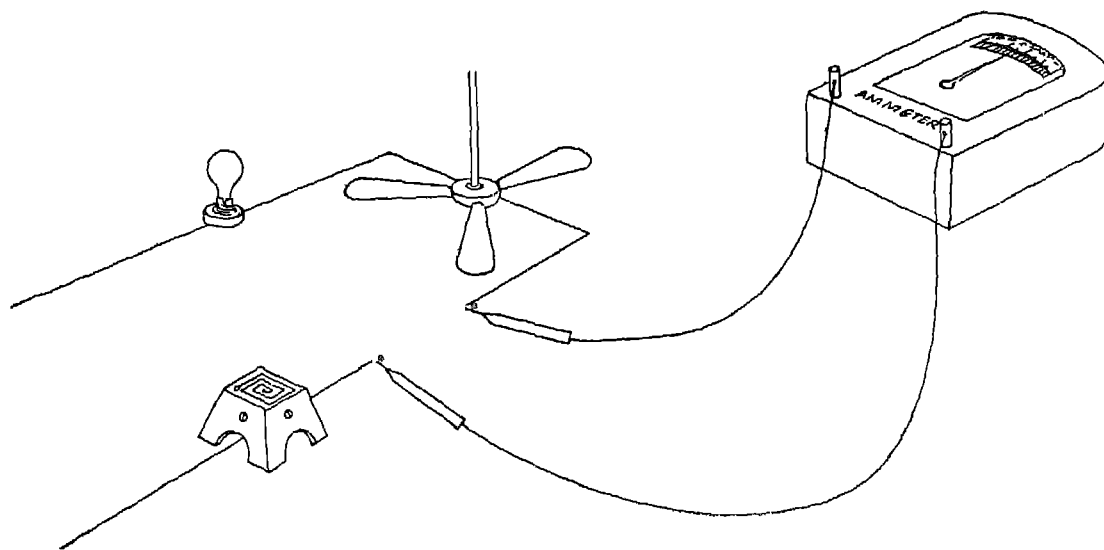


Fig. 7.3.A. The Ammeter is Connected in Series with the Circuit

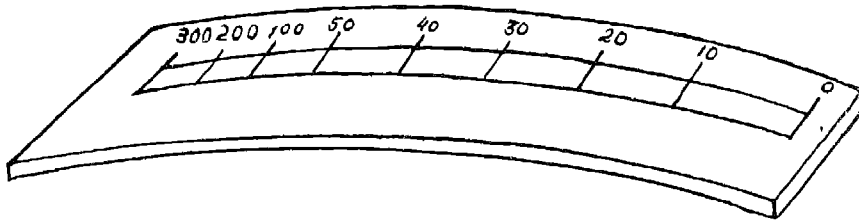
designed to measure alternating current (AC). The direct current ammeter is a polarized instrument. To operate this meter the test prod of the positive meter terminal must be connected to the positive side of the circuit; and the test prod of the negative meter terminal must be connected to the negative side of the circuit. The test prods of the alternating current ammeter, because it is designed to read alternating current, can be connected to either side of an alternating current circuit. An ammeter is properly connected, as shown in Figure 7.3.A, when it is in **SERIES** with the circuit. Notice that this implies the current can also be checked before the fan or light bulb, as long as the ammeter is connected in series with the circuit.

Four important precautions should be followed to protect the ammeter from damage.

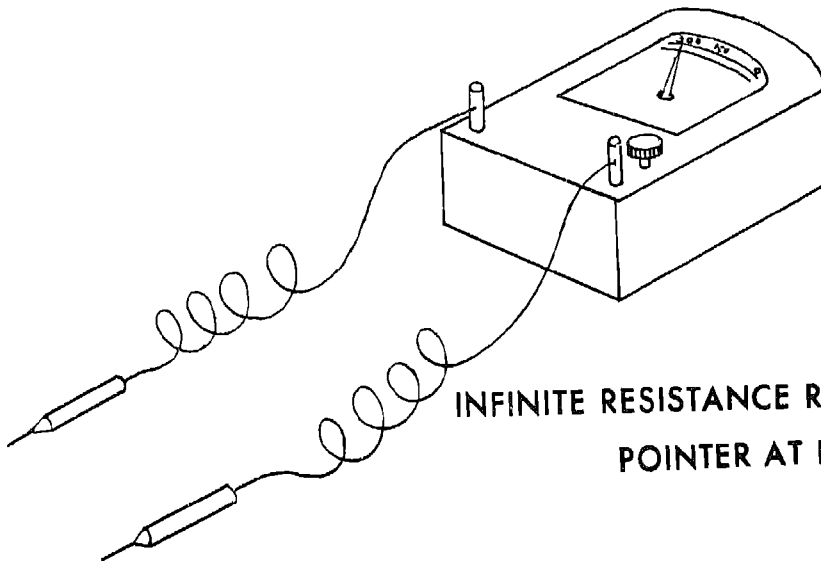
- (1) Select the correct ammeter for a direct current or alternating current circuit.
- (2) Be sure, the ammeter has a high enough reading scale to measure the current in the circuit.
- (3) Be sure, with a direct current circuit, to connect the positive and negative meter terminals to the correct side of the circuit.
- (4) Be sure, to always connect the ammeter in series with the circuit.

7.4 Ohmmeter

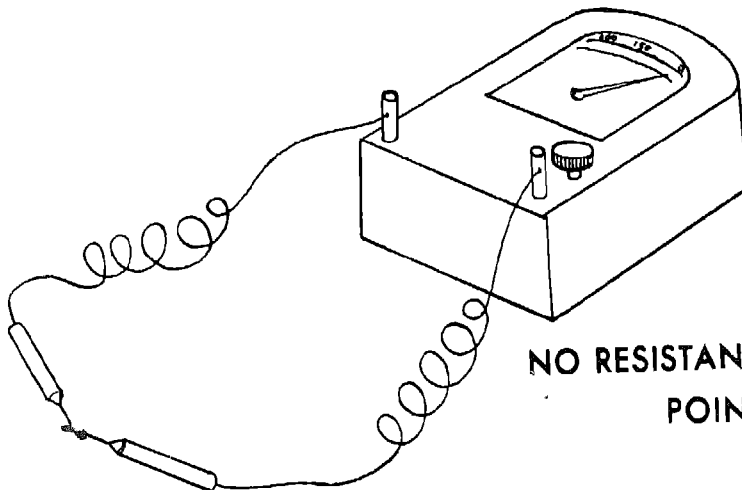
The ohmmeter is used to measure the resistance of a circuit in Ohms. The ohmmeter has its own internal source of electric power. It is usually a 1 1/2 volt dry cell battery. Therefore, the ohmmeter is **NEVER** connected to a live or hot electric circuit. Instead, when the ohmmeter is connected to a circuit, the value of the resistance is dependent upon the amount of voltage in the dry cell battery. The meter pointer, based upon the dry cell voltage, then moves to a scale position which indicates the value of the circuit resistance. Dry cell voltage decreases as the shelf life of a battery increases. Therefore, to obtain an accurate resistance reading, the ohmmeter, just before being used, should always be **zeroed**. To zero the ohmmeter touch the two test prods together, as shown in Figure 7.4.A, and move the zeroing knob until the pointer reads zero on the scale. When the test prods are directly touched together, and the scale reading adjusted to zero, there is no resistance indicated on the meter scale because there is no resistance between the test prods. When the test prods are separated the pointer should immediately move to a full scale reading because there is such great resistance between the test prods (in this case air) that the ohmmeter



OHMMETER SCALE UNEQUAL DIVISIONS



INFINITE RESISTANCE READING ON SCALE -
POINTER AT FULL SCALE



NO RESISTANCE READING ON SCALE -
POINTER AT ZERO

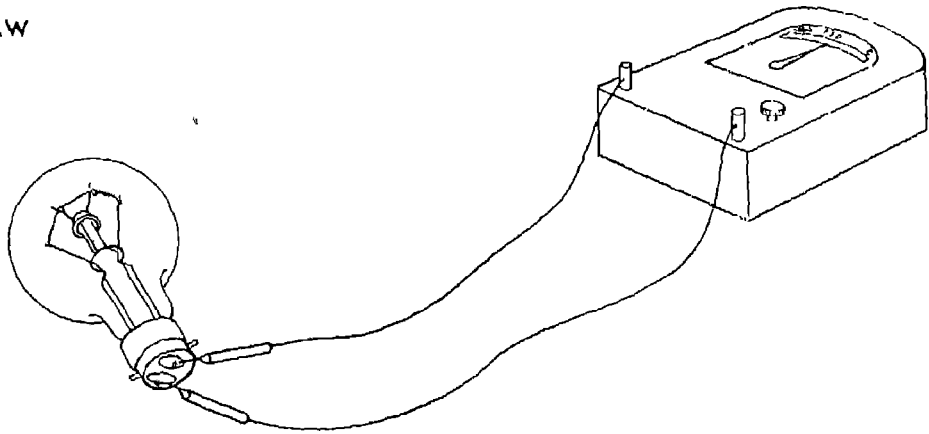
Fig. 7.4.A. The Ohmmeter Measures Resistance

OHM'S LAW

$$R = \frac{E}{I}$$

$$R = 110$$

$$R = \frac{220}{2}$$

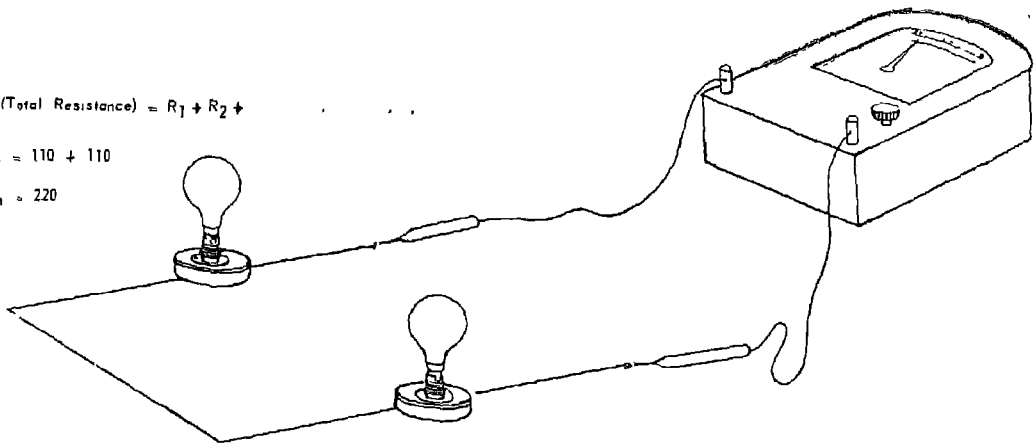


INDIVIDUAL ELECTRICAL APPARATUS

$$R_1 (\text{Total Resistance}) = R_1 + R_2 + \dots$$

$$R_1 = 110 + 110$$

$$R_1 = 220$$

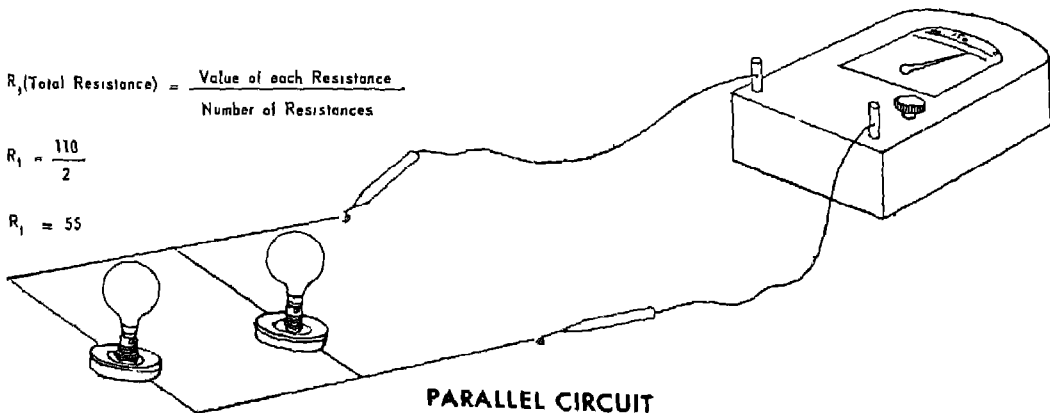


SERIES CIRCUIT

$$R_1 (\text{Total Resistance}) = \frac{\text{Value of each Resistance}}{\text{Number of Resistances}}$$

$$R_1 = \frac{110}{2}$$

$$R_1 = 55$$



PARALLEL CIRCUIT

Fig 7.4.B. Ohmmeter Measuring Resistance of Circuits

reads infinite resistance. As different pieces of electrical apparatus, with a resistance of 0 to 300 ohms, are placed between the test prods, the meter scale will indicate their resistances in ohms.

The scale of an ohmmeter is difficult to read because it is divided unevenly. To interpret the scale correctly read the number of main divisions and observe closely the number of sub-divisions into which each main division is divided.

The ohmmeter, as shown in the lamp example in Figure 7.4.B, can be used to measure the resistance of each individual piece of electrical apparatus. The ohmmeter, by touching the test prods to the ends of the circuit, can also be used to measure the total amount of resistance in a series circuit and a parallel circuit. Each type of ohmmeter measurement, as shown by the computations, can also be determined by an electrical formula. A description of each formula with complete computations can be found in the section on Electrical Measurement. It is interesting to compare the result of the visual ohmmeter readings, as one conducts various electrical experiments with the answers computed by electrical formulas.

One of the most important uses of the ohmmeter, as shown in Figure 7.4.C, is for *trouble shooting* purposes. When the circuit of an electrical apparatus is good, as shown with the continuous coil of wire around the iron core, the ohmmeter reading indicates the correct amount of resistance. If the circuit of an electrical apparatus is *open*, as shown with the break in the coil of wire around the iron core, the ohmmeter reading indicates a higher resistance. If the circuit of an electrical apparatus is *shorted*, as shown with the bare wire in direct contact with the iron core, the ohmmeter reading indicates a lower resistance. Trouble shooting various types of apparatus by this method will indicate whether the electrical circuit in the apparatus is good, open or shorted.

Four important precautions should be followed to protect the ohmmeter from damage.

- (1) Be sure the power to the circuit being tested is turned OFF.

- (2) Be sure the ohmmeter has a high enough reading scale to measure the resistance in the circuit.
- (3) Be sure, because the ohmmeter is powered by a dry cell, to ZERO the pointer on the scale.
- (4) Be sure, if the ohmmeter has a switch, to turn it to the OFF position when the meter is not in use.

8. ELECTRICAL TEST PANEL

8.1 Teacher-Student Electrical Test Panel

The electrical test panel, as shown in Figure 8.1.A, is suggested as one of the best types of educational training aids for the teacher to adequately supervise the training of students in the proper use of electrical apparatus and equipment.

The wood back of the electrical test panel can be made out of a $3/4" \times 4' \times 8'$ piece of plywood. The shelf can be made from a $3/4" \times 2' \times 8'$ piece of plywood. The student wire boards are approximately $1" \times 6" \times 30"$ in size, and for easy mounting of electrical parts are made from soft wood. The wood pegs, for quick and easy mounting of the student wire boards, are fastened permanently to the plywood back of the electrical test panel. The wood corner blocks, to prevent the student wire boards from swinging, are also mounted permanently to the plywood back of the electrical test panel.

The electrical parts of the test panel include a watt-hour meter, disconnect switch box, fuse box, two pin plugs and three pin plugs. The complete wiring of the electric test panel, for safety reasons, should be done behind the test panel. The only exposed wiring should be during testing when the students hang up their electrical test boards. It would be advisable, because of the extra-heavy loads that may at times be put on the test panel, to wire the main line up to the fuse box with type CTS, 30 ampere, 7/20 twisted strand wire. Each two and three

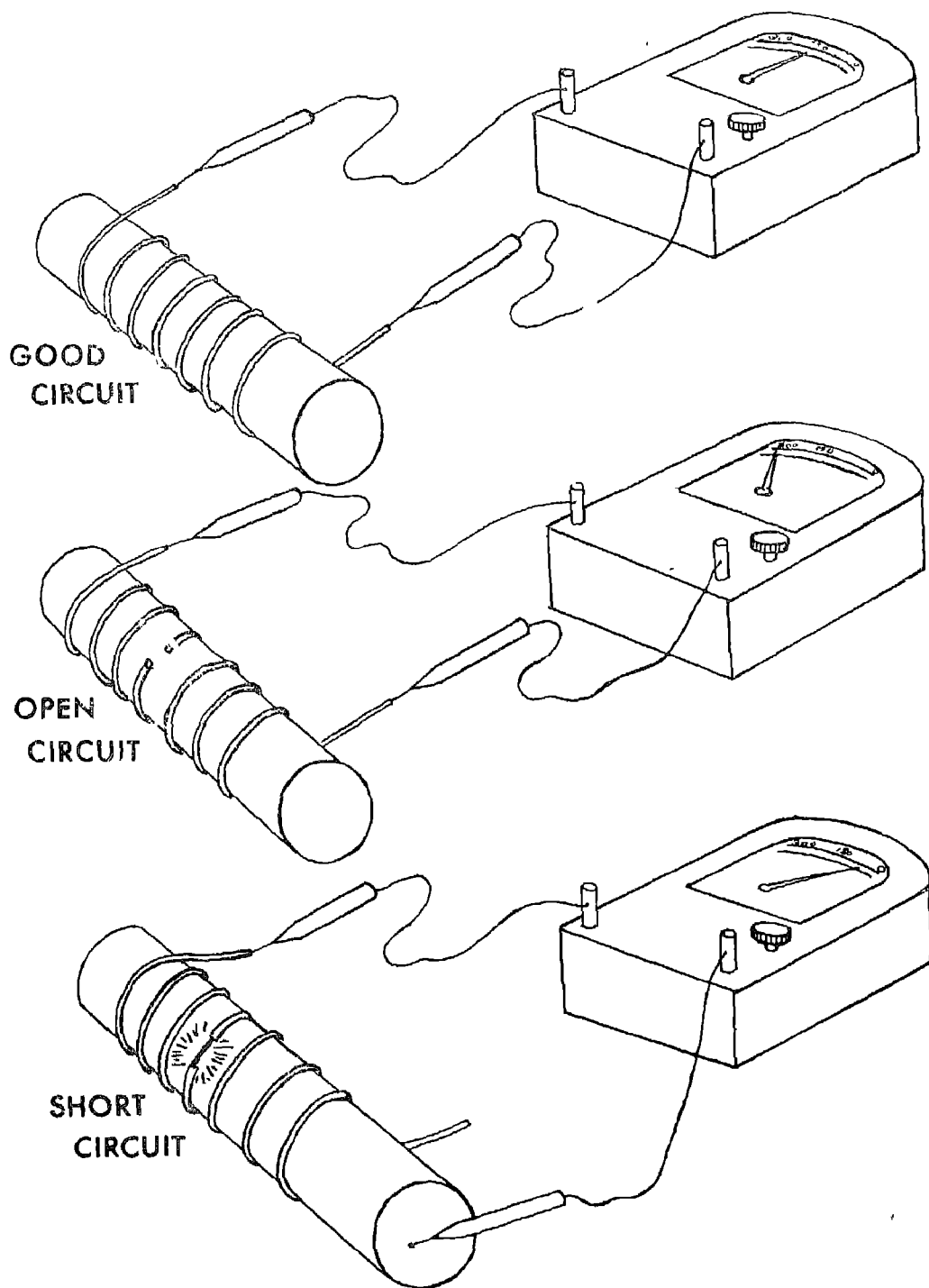


Fig. 74.C. Ohmmeter—Trouble Shooting Circuits

HOUSE WIRING

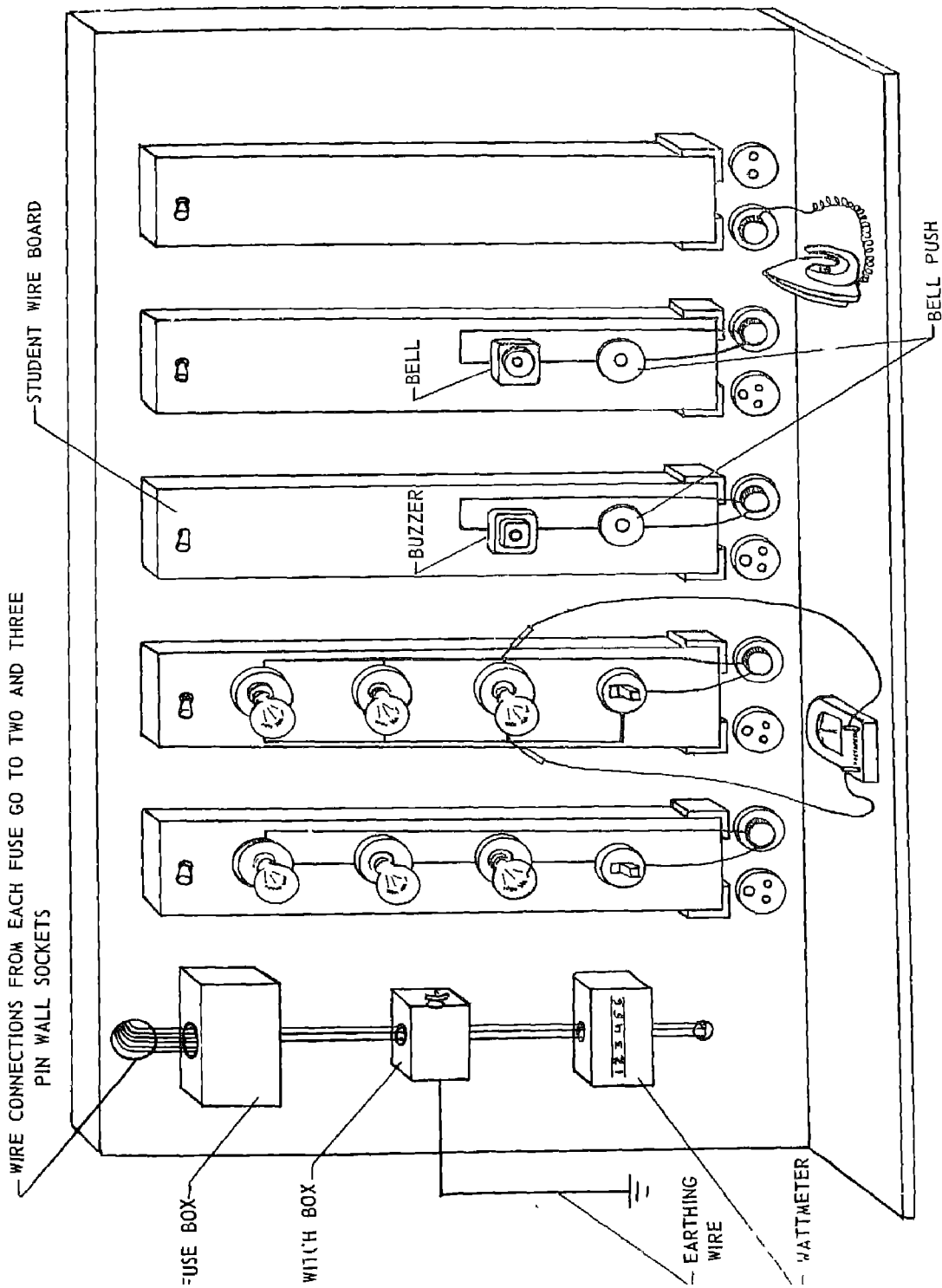


Fig 81 A Electrical Test Panel

pin plug should be wired with type CTS, 15 ampere, 7/22 twisted strand wire. These and other possible size wires may be checked and selected from TABLE II—HOUSE WIRE DATA.

8.2 Safety Precautions

There are two *safety precautions* a technology teacher should become aware of and incorporate into the construction of the electrical test panel.

- (1) The permanent installation of a good earthing connection. As a reminder, Figure 8.1.A, shows an external ground connection. The watt-hour meter, disconnect switch box, fuse box and three pin sockets should all be connected permanently to a good earthing connection.
- (2) The permanent installation of an insulated floor area where the students will stand in front of the electrical test panel. A cement floor could be very dangerous because it holds moisture. A good insulation to use on top of a cement floor is a wood platform or a thick rubber mat.

9. SUGGESTED ELECTRICAL EXPERIMENTS AND PROCEDURES FOR STUDENTS (WITH EXAMPLES)

9.1 Suggested Electrical Procedures

A suggested list of electrical experiments has been developed in this section as an example of the type of practical experiences in which the teacher should encourage the students to engage. Each time a student undertakes one of the series circuit or parallel circuit experiments, as suggested in number, "9.2 Suggested Electrical Experiments" he should for correct training follow the 11 steps in Teacher Precautions. Students should be encouraged to complete all of the suggested experiments.

It should be pointed out to the teacher that *student precautions* and *teacher precautions* have

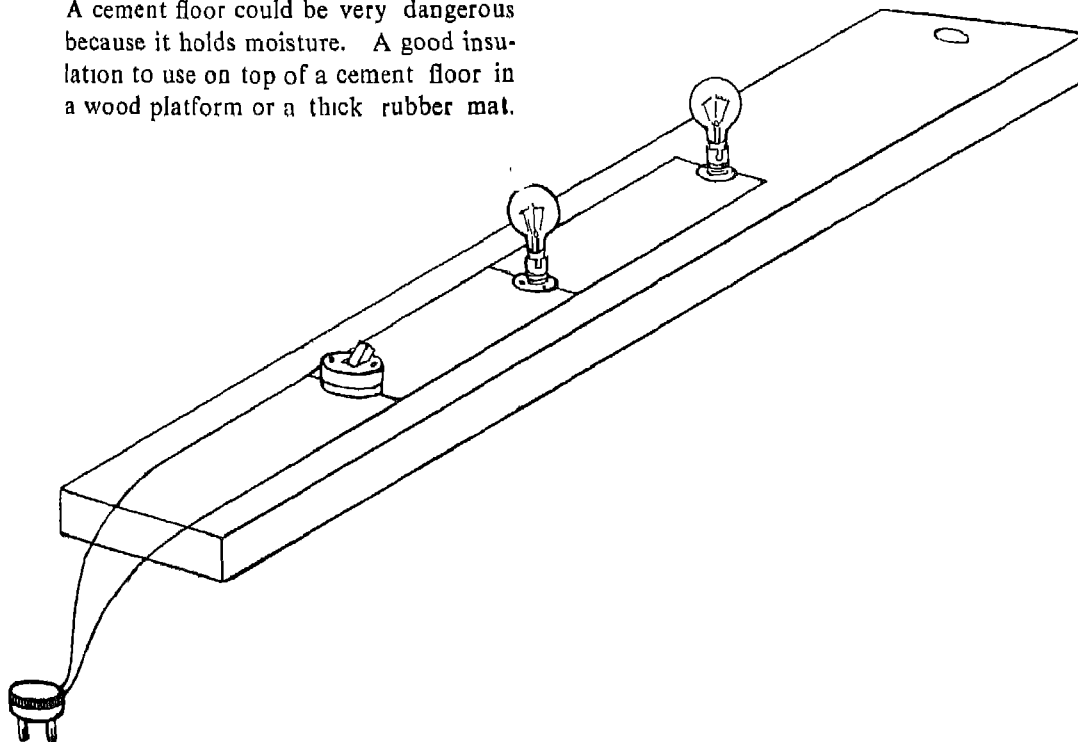


Fig. 9.2.A Example of Pictorial Representation Hook up on a Student Wire Board (Parallel Circuit Experiment, with Two Lamps, One Switch and One Plug)

been inserted at critical instructional points in the experiments. Both the teacher and the students should become aware, during any experiment, of the educational importance attached to correct technological training.

The *Electrical Measurement Data* form, as shown in TABLE III, is a suggested method for the student to easily record his electrical measurements, for each experiment he undertakes. It is also a good record-keeping method for the teacher as it shows evidence of the student's quality of work.

The *Students Grade Sheet for Electricity Experiments*, as shown in TABLE IV, is a suggested method for the teacher to keep accurate records pertaining to the work each student accomplishes in the electricity class.

9.2 Suggested Electrical Experiments

- (1) Make a pictorial drawing of each wire board circuit. (Figure 9.2.A).
- (2) Make a schematic drawing of each wire board circuit (Figure 9.2.B).
- (3) Hook up each wire board experiment at the students' workbench.

SERIES CIRCUIT EXPERIMENTS

2 Lamps	1 Switch	1 Plug
3 Lamps	1 Switch	1 Plug
4 Lamps	1 Switch	1 Plug
1 Bell	1 Bell Push	1 Plug
1 Buzzer	1 Bell Push	1 Plug

PARALLEL CIRCUIT EXPERIMENTS

2 Lamps	1 Switch	1 Plug
3 Lamps	1 Switch	1 Plug
4 Lamps	1 Switch	1 Plug

STUDENT PRECAUTIONS

- (a) Connect the live wire through the switch.
- (b) Make all splices according to accepted electrical practices.
- (c) Make all terminal connections according to accepted electrical practices

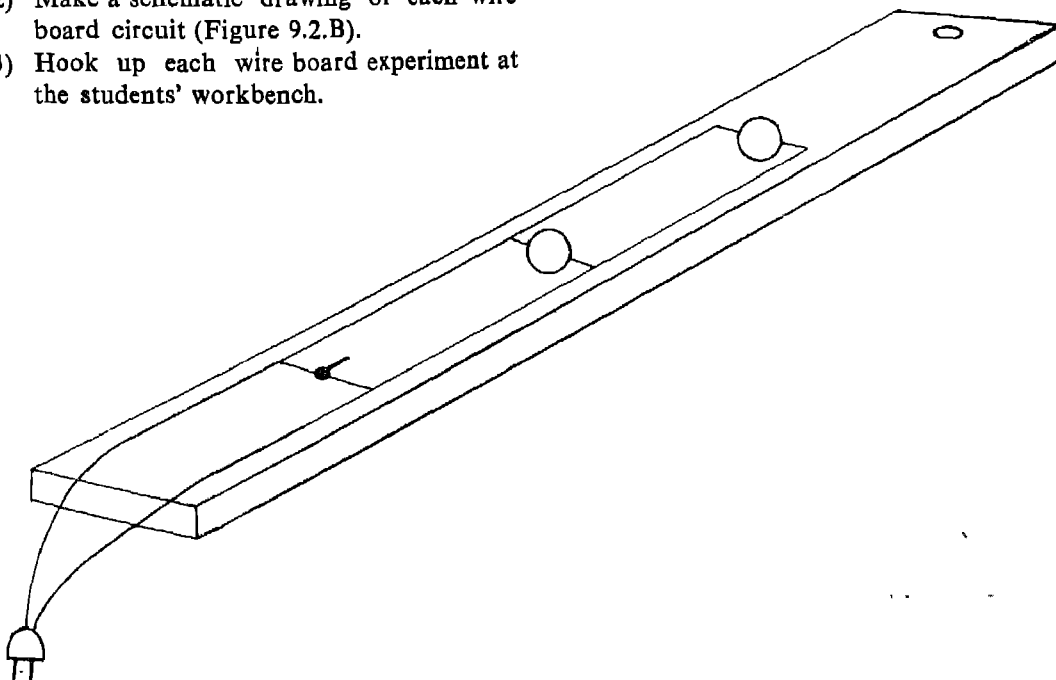


Fig 9.2 B. Example of Schematic Representation Hook up on a Student Wire Board
(Parallel Circuit Experiment with Two Lamps, One Switch and One Plug)

TEACHER PRECAUTIONS

- (a) Make each student responsible for asking the teacher to inspect the wire board hook up, as a safety policy, while at his workbench.
- (b) Check students wire board hook up thoroughly for proper electrical connections.
- (c) Give student permission, after thorough checking, to proceed to the electrical test panel.
- (d) Instruct students in the proper use of the Electrical Test Panel.
- (4) Hang the wire board experiment on the electrical test panel.
- (5) Check the disconnect switch for OFF position.
- (6) Wire the fuse holder with the correct size fuse wire for the experiment.
- (7) Insert the two or three pin plug into the wall socket.

- (8) Throw the disconnect switch to the ON position.
- (9) Activate the electric experiment by throwing the circuit switch ON.
- (10) Electrical Measurement Experiments.

VOLTMETER

- (a) Check the voltage across each apparatus.
- (b) Check the total voltage of the circuit.

AMMETER

- (a) Check the amperage of each apparatus.
- (b) Check the total amperage of the circuit.

OHMMETER

- (a) Check the resistance of each apparatus.
- (b) Check the total resistance of the circuit.
- (11) Record the Electrical Measurement Data.

TABLE III

ELECTRICAL MEASUREMENT DATA FORM

Student's Name APPARATUS	Type of Experiment VOLTMETER READINGS	Class AMMETER READINGS	Date OHMMETER READINGS
1			
2			
3			
4			
5			
6			
TOTAL CIRCUIT			

10. SUGGESTED MAINTENANCE EXPERIMENTS FOR STUDENTS

10.1. Maintenance Repair

Maintenance repairs are very interesting to boys if the apparatus that needs repair personally belongs to the boy or his family. Therefore, a boy should be encouraged to bring into the electrical shop for proper maintenance and repair, various types of electrical apparatus that he may have in his home.

The teacher may also solicit from other teachers, the school, or people in the community, any type of electrical apparatus that can be repaired as a part of the educational teaching procedure in the electricity shop.

A suggested list of electrical items for proper maintenance and repair, as shown below, should include experiences from the very simple to the more complex.

10.2. Accessories

- (1) Wall Socket
- (2) Multiple Power Plug
- (3) Multiple Light Plug
- (4) Two Pin Plug Top
- (5) Three Pin Plug Top
- (6) Switch
- (7) Fixed Type Light Holder
- (8) Pendant Type Light Holder
- (9) Bell
- (10) Fuzzer

10.3. Appliances

Replace a plug, cord or switch on the following:

- | | |
|------------|-------------|
| (1) Lamp | (5) Toaster |
| (2) Fan | (6) Mixer |
| (3) Heater | (7) Radio |
| (4) Iron | (8) Clock |

11. SUGGESTED HOUSE WIRING INSTALLATION PROBLEMS AND PROCEDURES FOR STUDENTS (WITH EXAMPLES)

11.1. Student Designed House

Students should be encouraged, after studying the entire section on House Wiring, to utilize this information by developing a complete electrical installation for a house. The problem could be a simple approach by making a complete electrical installation for a one room house. Or, the problem could be made more advanced by designing a complete electrical installation for a large modern house.

11.2. Example of House Wiring Installation

The example of a house wiring installation, as developed in this section, is for a large modern house. The purpose of this is to show the type of thorough planning, from an educational point of view, that can become a part of the students' learning experience. The house has been deliberately planned with heavy electrical requirements to insure the presentation of sufficient ideas that the teacher and students can draw upon in designing their own electrical installations

- (1) Draw a *House Floor Plan*, as shown in Figure 11.2.A, with complete electrical requirements
- (2) Make a table, as shown in TABLE V, listing the *House Wiring Installation, Accessory and Apparatus Estimates for Light*. List the accessories and apparatus you desire to have in your house. Also estimate the total watts required in each room and for the entire house, as recommended by *Indian Standard Code of Practice for Electrical Wiring Installations (System Voltage not exceeding 650 volts)*².

2. Indian Standard, IS.732-1963, under General Requirements 3.12, recommends that incandescent lamps shall be rated at 60 watts, unless otherwise specified. Ceiling fans, table fans and ordinary socket outlets shall be rated at 60 watts and fluorescent lamps at 40 watts.

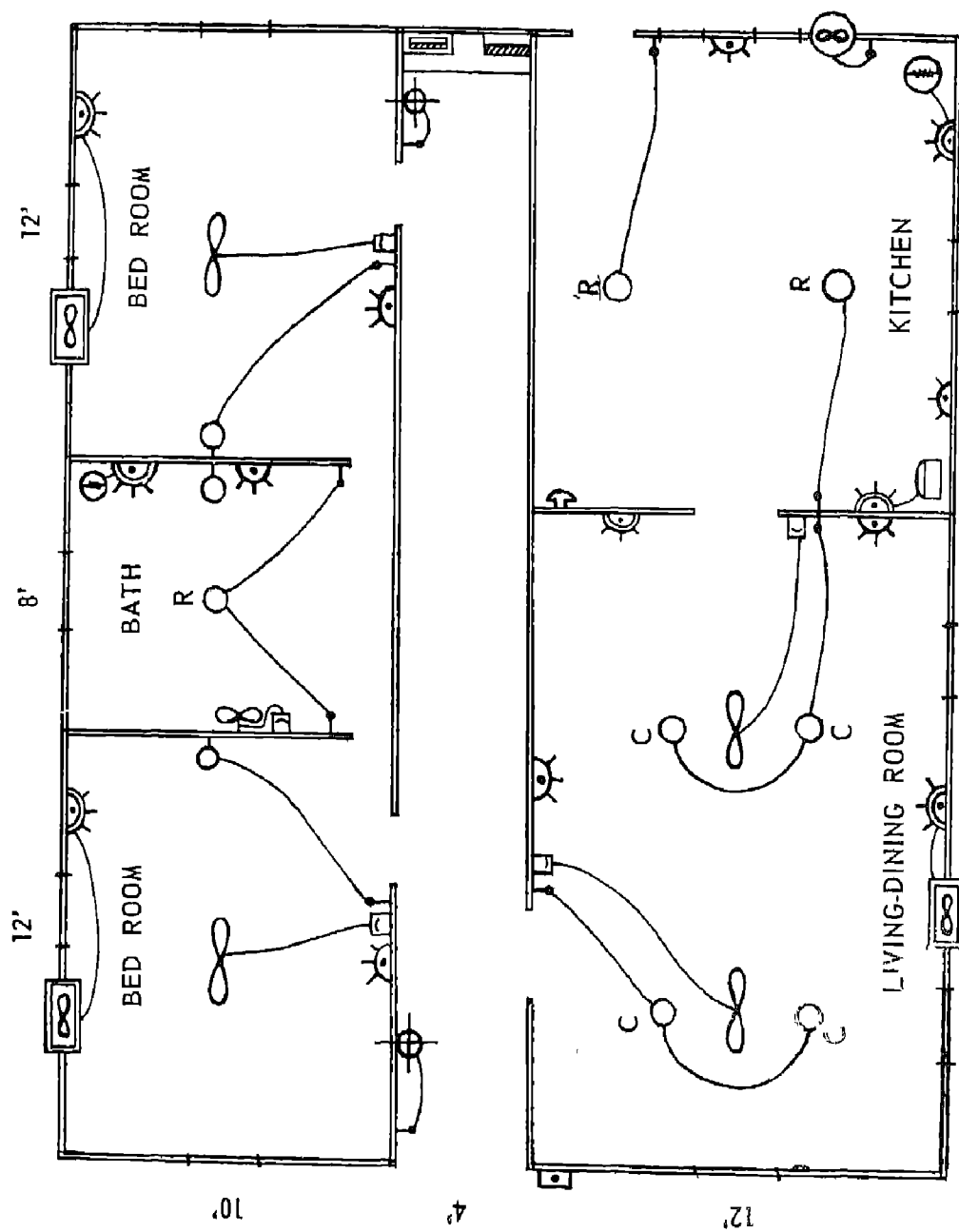


Fig. 11.2.A. House Floor Plan with Suggested Wiring Installation

<u>CONTROL GEAR AND DISTRIBUTION FUSE-BOARDS</u>		<u>SOCKET OUTLETS</u>	
Distribution fuse-board with switches, lighting		Socket-outlet and switch combined, 3 pin 5 A	
Distribution fuse-board with switches, power		Socket-outlet and switch combined, 3 pin 15 A	
<u>CEILING OUTLETS</u>		<u>FIXED HEATING OUTLETS</u>	
Rod pendant		Self-contained electric water heater	
Chain pendant		<u>BELLS AND BUZZERS</u>	
Light bracket			
<u>SWITCH OUTLETS</u>		<u>FIXED APPARATUS OUTLETS</u>	
One-way switch		Bell push	
<u>OTHER SYMBOLS</u>		Bell	
Pilot or corridor lamp		Ceiling fan	
Refrigerator		Bracket fan	
Air Conditioner		Exhaust fan	

Fig 11.2.A. Conventional Electrical Symbols for House Floor Plan

TABLE IV
STUDENTS GRADE SHEET FOR ELECTRICAL EXPERIMENTS

[illegible]

TABLE V

HOUSE WIRING INSTALLATION,
ACCESSORY AND APPARATUS ESTIMATES FOR LIGHT

ACCESSORIES AND APPARATUS			LIVING ROOM	DINING ROOM	KITCHEN	PANTRY	CORRIDOR	BED ROOMS			BATH ROOMS			WATTS	
Items	Rated Watts	1						2	3	1	2	3	Item	Totals	
CEILING OUTLETS (LAMPS)															
Single Light Pendant	60														
Counter Weight Pendant	60														
Rod Pendant	60			120						60			180		
Chain Pendant	60	120	120										240		
Light Bracket	60							60	60	60			180		600
SOCKET OUTLETS															
Socket-outlets, 3 pin 5 A	60														
Socket-outlet and switch Combined 3 pin, 5 A	60	60	60	120				60	60	60			420		420
FANS															
Ceiling	60	60	60					60	60				240		
Wall	60									60			60		300
CORRIDOR LAMP															
	40						80						80		80
DOOR BELL	0														
DOOR BUZZER	0														
TOTAL WATTS		240	240	240			80	180	180		240				1400

- (3) Make a table as shown in TABLE VI, listing the *House Wiring Installation, Accessory and Apparatus Estimate for Power*. List the accessories and apparatus you desire to have in your house. Also estimate the total watts required in each room and for the entire house. It should be pointed out to students studying the procedures for estimating the total power needs for a house, that only a portion of the total electrical requirements needed will be allocated by the light and power company. Electrical engineers, as a quick method of calculation, many times use a point system to estimate the electrical needs for a house. Each POINT (Electrical outlet required) is allocated 500, or preferably 1000 watts³. This is a practical method of determining the amount of electricity that will be allocated to a house by the light and power company. However, the watt system will point out to the student the standard procedure used to estimate the full power requirements needed for his house.
- (4) Make a table as shown in TABLE VII, listing the *House Wiring Installation, Circuit Requirement for Light*. The total amount of watts required for each accessory and apparatus item can be obtained from your estimates in TABLE V. Lights in a house for example, are never turned on all day long or at once. However, a ceiling fan during the hot season may operate both day and night. Socket outlets are usually used only a small percentage of the time. Because of all of these variations light estimates are usually calculated on a percentage basis. The percentage basis may also vary according to your needs.
- (5) Make a table, as shown in TABLE VIII, listing the *House Wiring Installation, Circuit Requirement for Power*. The total amount of watts required for each room can be obtained from your estimates in TABLE VI. Calculate the number of amperes needed for each room. According to the amount of amperes calculated for each room, select the proper size fuse that will provide adequate safety protection for that room. The total amounts will indicate the exact power requirements for your house. Also calculate the amount of power allocated, under the point system, by your local municipal board or light and power company. The point system will provide a quick estimate of the actual amount of power that will be allocated to the house by the light and power company. However, the watt system will point out to the student the standard procedure used to estimate the full power requirements needed for his house.
- (6) Make a table, as shown in TABLE IX, listing the *House Wiring Installation, Branch Circuit Requirement for Light*. The selection or arrangement of rooms, lights, fans and outlets that are connected to a specific branch circuit depends upon several factors:
- (a) Economy of installation should be considered.
 - (b) The size of the wire needed to safely operate the light system. For this house a twisted strand, size 3/22, 5 ampere wire has been selected.
 - (c) The total amount of amperes required to operate the branch light circuits. The total amount of watts required to operate the light system for this house, on a percentage basis, is approximately 637 watts.

3. Indian Standard, IS-732-1963, under General Requirements 3.12 recommends that power socket outlets be rated at 1,000 watts, unless the actual values are known or specified,

$$\begin{aligned} 637 \text{ WATTS} \div 220 \text{ VOLTS} \\ = 2.91 \text{ AMPERES} \end{aligned}$$

TABLE VI

HOUSE WIRING INSTALLATION
ACCESSORY AND APPARATUS ESTIMATES FOR POWER

ACCESSORIES AND APPARATUS		LIVING ROOM	DINING ROOM	KITCHEN	PANTRY	BED ROOMS				BATH ROOMS			ITEM TOTALS	
Item	Rated Watts					1	2	3		1	2	3	Watts	Points
SELF-CONTAINED ELECTRIC WATER HEATER	1000			1000						1000			2000	2
	2000													
REFRIGERATOR	500			500									500	1
EXHAUST FAN	150			150									150	1
ELECTRIC UNIT HEATER	500													
	1000													
	1500													
AIR COOLER	300													
AIR CONDITIONER	1750	1750				1750	1750						5250	3
SOCKET OUTLETS														
Socket-outlet, 3 pin 15 A	1000													
Socket-outlet and switch combined, 2 pin 15 A	1000													
Socket-outlet and switch combined, 3 pin 15 A	1000		1000										1000	1
TOTAL WATTS		1750	1000	1650		1750	1750			1000			9800	8

TABLE VII
HOUSE WIRING INSTALLATION
CIRCUIT REQUIREMENT FOR LIGHT

ACCESSORIES AND APPARATUS ITEMS	TOTAL ESTIMATED WATTS	PERCENT OF USE	TOTAL WATTS NEEDED
LAMPS	600	50	300
CORRIDOR LAMPS	80	50	40
FANS	300	50	150
SOCKET OUTLETS	420	35	147
TOTALS	1400		637

TABLE VIII
HOUSE WIRING INSTALLATION
CIRCUIT REQUIREMENT FOR POWER

ROOM	NEEDED			ALLOCATED UNDER THE POINT SYSTEM				
	Watts	Amperes	Fuse Size	Points	Watts	Amperes	Fuse Size	
LIVING ROOM	1750	7.9	10	1	1000	4.5	5	
DINING ROOM	1000	4.5	5	1	1000	4.5	5	
KITCHEN	1650	7.5	10	3	3000	13.6	15	
BED ROOMS 1	1750	7.9	10	1	1000	4.5	5	
2	1750	7.9	10	1	1000	4.5	5	
BATH ROOM	1000	4.5	5	1	1000	4.5	5	
TOTALS	8900	40.2	50	8	8000	36.1	40	

TABLE IX
HOUSE WIRING INSTALLATION
BRANCH CIRCUIT REQUIREMENT FOR LIGHT

NUMBER OF BRANCH CIRCUIT	LIVING ROOM	DINING ROOM	KITCHEN	CORR- IDOR	BED ROOMS			BATH ROOM	WATTS				AMPERES	FUSE SIZE	
					1	2	3		Required	Percentage of Use					Total Percentage Per Branch Circuit
										Watts	%				
LIGHT	2	2	2						360	180	50	324	1 47	3	
1 FAN	1	1						120	60	50					
OUTLET	1	1	2					240	84	35					
LIGHT				2	1	1		2	320	160	50	313	1 44	3	
2 FAN					1	1		1	180	90	50				
OUTLET					1	1		1	180	63	35				
TOTALS									1400	637		637	2 91		

Therefore, the electrical engineer has a choice of designing the house with one branch circuit with a 5 ampere fuse, or two branch circuits with 3 ampere fuses. Two branch circuits have been selected because it provides the opportunity to expand the house lighting requirements more easily in the future if desired.

- (d) The total amount of amperes required to operate each branch light circuit.

The light branch circuit percentages for this house, when calculated according to load requirement, fall within the safe fuse size of 3 amperes.

CIRCUIT 1 324 Watts $\div$ 220 Volts
= 1.47 Amperes

CIRCUIT 2 313 Watts $\div$ 220 Volts
= 1.44 Amperes

- (7) Make a table, as shown in TABLE X, listing the *House Wiring Installation, Branch Circuit Requirement for Power*. The selection or arrangement of rooms, accessories and apparatus that are connected to a specific branch circuit depend upon several factors.

(a) Branch Circuit Factors

- (i) Economy of installation should be considered.
- (ii) The size of wire needed to safely operate the light system. For this house a twisted strand, size 7/22, 15 ampere wire has been selected.
- (iii) The total amount of amperes required to operate each branch circuit.

Certain branch circuit limitations must be taken into consideration when estimating the power requirements for this house.

(b) Branch Circuit Limitations

- (i) According to the number of points (Total electrical outlets of all types) designed in the

house, only 8 KW (8,000 WATTS) will be allocated by the light and power company.

POINT SYSTEM OF CALCULATION

Estimated Points	= 8
Each Point	= 1,000 Watts
Total Watts	= 8×1000
Total Watts	= 8,000
1,000 Watts	= 1 KW (Kilowatt) of Power
KW	= $8,000 \div 1000$
KW	= 8

- (ii) According to the watts system of calculation 9 KW (9,000 WATTS) of power is actually needed to adequately meet the electrical requirements of this house.

WATT SYSTEM OF CALCULATION

1,000 WATT	= 1 KW (Kilowatt) of Power
KW	= $9,000 \div 1000$
KW	= 9

- (iii) The difference between the amount of allocated power and needed power makes it necessary to devise some system for the satisfactory operation of the electrical appliances in the house. To operate the electrical equipment within the allocated amount of power will be a slight inconvenience. However, the branch circuits have been specifically allocated certain electrical apparatus to permit turning them on and off as desired or needed. The only electrical apparatus that must run continuously is the refrigerator. Also, all socket outlets with combined switches have been specifically selected. This

TABLE X
HOUSE WIRING INSTALLATION
BRANCH CIRCUIT REQUIREMENT FOR POWER

NUMBER OF BRANCH CIRCUIT	LIVING ROOM	DINING ROOM	KITCHEN	BED ROOM	BATH ROOM	TOTAL WATTS	AMPERES	FUSE SIZE
1	Air Conditioner 1750 W	Socket Outlet 1000 W				2750	12.5	15
2			Refrigerator 500 W Exhaust Fan 150 W			650	3.0	5
3			Water Heater 1000 W		Water Heater 1000 W	2000	9.1	10
4				Air Conditioner 1750 W		1750	7.9	10
5				Air Conditioner 1750 W		1750	7.9	10
TOTALS						8900	40.4	

permits any electrical apparatus to be temporarily turned off and disconnected if the socket outlet

is needed for operating some other piece of electrical apparatus.

STUDY QUESTIONS

The House Wiring Unit contained many important ideas and practices of electricity that you should understand. The following questions have been listed as types that your instructor will use for internal grading. Therefore, review this unit well until you are able to answer all the questions easily and correctly. If you are unable to understand the questions or find the answers, please see your instructor for help.

ESSAY QUESTIONS

Essay questions should be designed to provide the student with the opportunity to express, in writing, technical information on a limited subject. Each student can be assigned a different topic, or the same topic. The advantage of different topics is that it will provide the teacher with a broader reaction to all of the materials studied.

1. Describe how electricity is generated and transmitted.
2. Describe, in detail, how electricity enters the home.
3. Describe all of the information an electrician should know about wire.

4. Select one of the small accessories used as part of the electrical installation in a house, (such as a lamp, switch, or fuse), and describe, in detail, the technical information an electrician should know about each accessory.
5. Describe the operation of the ohmmeter and give various applications of its use.

TRUE AND FALSE QUESTIONS

The following statements are either TRUE or FALSE. Fill in the blank at the left of the number with a + sign for true questions and a O sign for false questions.

- _____1. Generators are usually designed to produce 13,000 volts of electricity.
- _____2. The neutral wire in electricity is referred to as the LIVE or HOT wire.
- _____3. The watt-hour meter measures the electricity consumed in units of kilowatt-hours (kwh).
- _____4. A fuse is a soft piece of metal that will melt at a specified temperature.
- 5 Alternating current travels in one direction,

- 6 The metal most commonly used for house wire is copper.
- 7. Rosin powder is the best type of flux for electrical connections.
- 8. A three-pin, multiple lamp plug has no earthing wire terminal.
- 9. A porcelain connector is used for a solderless connection, where two or more wires are to be connected together.
- 10. A gutti is properly mounted into a wall by placing the large end of the gutti into the hole first.
- 9. The type of current generated by Indian power stations is called ... current.
- 10. Three types of splices used in the house wiring are the... , ... and

MULTIPLE CHOICE QUESTIONS

The following statements will all be true with the addition of one or more words. Place the number of the word, or group of words, that correctly completes the sentence in the blank to the left of the question number.

COMPLETION QUESTIONS

The following statements will all be true with the addition of one or more words. Fill in the blank to the left of the number with the correct word or words that completes the sentence.

- 1. The plant harnesses the force of flowing water to mechanically operate the generators that produce the electric energy.
- 2. A ... is capable of greatly increasing the voltage for transmission to any desired higher voltage.
- 3. Transmission lines carry voltages as high as or ... volts.
- 4. The transmission of excessively high voltages is necessary because of the large ... (loss of power) over many miles of wire.
- 5. The ... prevents the electricity from between the wires, or the transmission poles.
- 6. The... is designed to permit the service drop to enter the house in a safe manner.
- 7. The... permits all of the electricity in the house to be shut off.
- 8. The..... connects the metal frames of all the electrical accessories directly to the ground.
- 1. energy mechanically operates the generators that produce the electricity.
(1) Heat (3) Steam
(2) Mechanical (4) Electric
- 2. Transmission lines made of ... are usually used on long expanses between transmission towers.
(1) brass (3) steel
(2) aluminium (4) copper
- 3. The type of current generated by power stations in India, makes... complete cycles every second.
(1) 30 (3) 50
(2) 40 (4) 60
- 4 The power consumed in an electric circuit is called a.....
(1) volt (3) ampere
(2) ohm (4) watt
- 5. When a lamp burns out in a parallel circuit containing four lamps, it causes ... lamp(s) to go out.
(1) one (3) three
(2) two (4) four

PROBLEM QUESTIONS

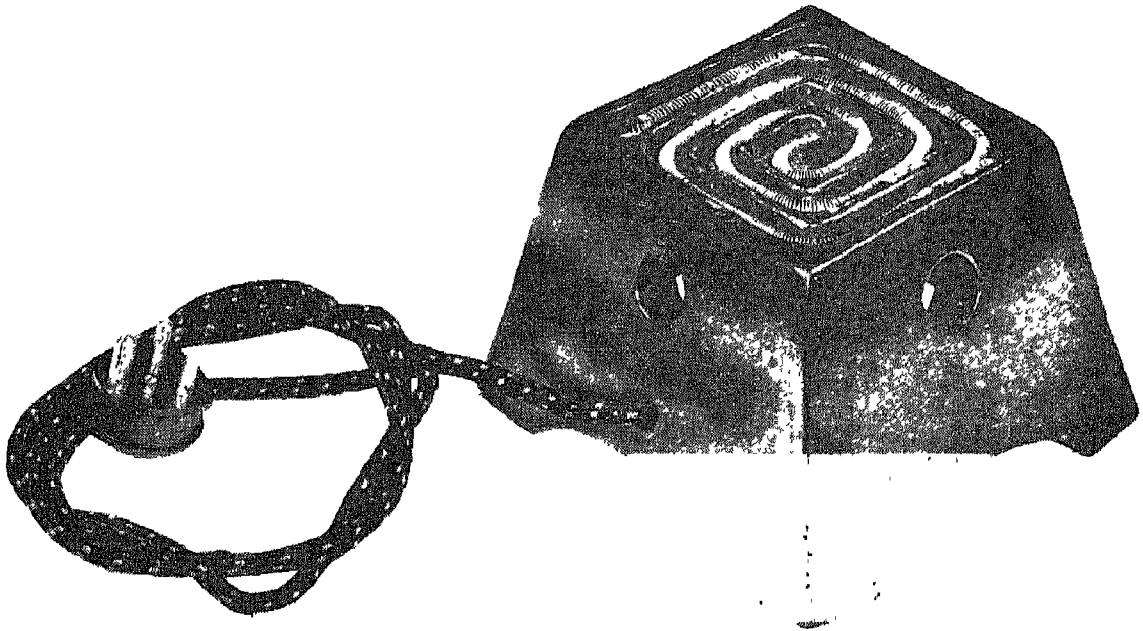
Problem questions should be designed to provide the student with the opportunity to express, in writing, technical information on a limited problem.

Each student can be assigned a different problem. The advantage of different problems is that it will provide the teacher with a broader reaction to all of the materials studied. Students

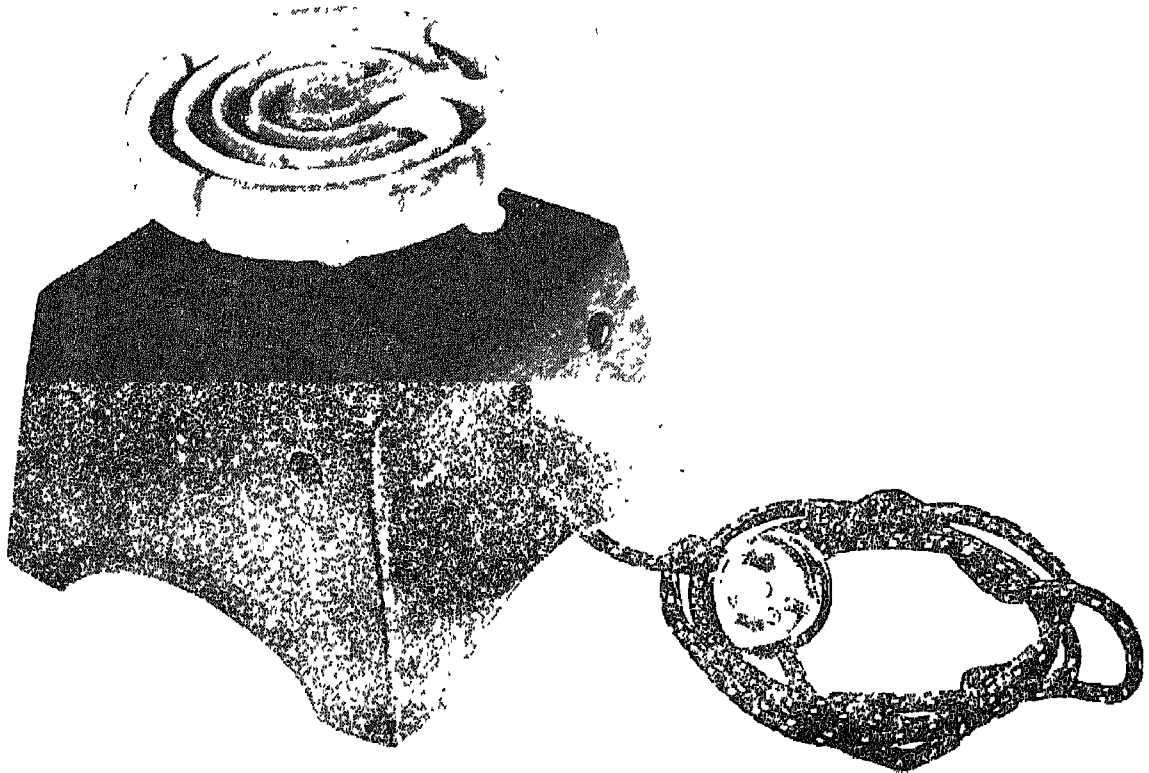
should be required to show the correct procedure for solving the problem and include all calculations.

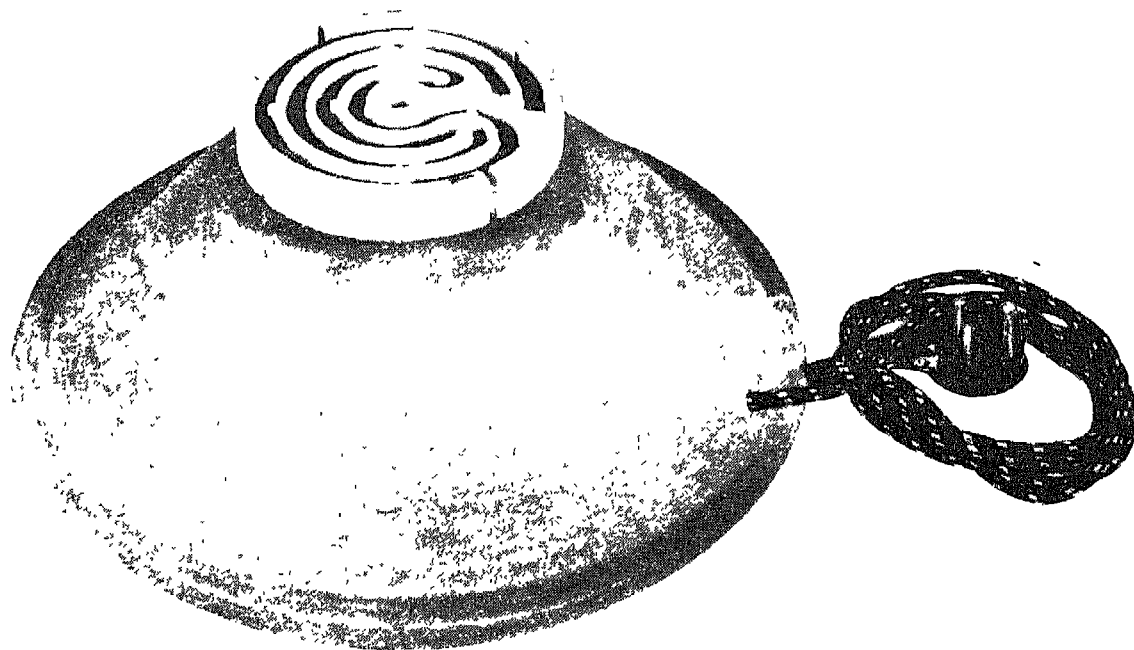
1. Light Rate Problem. The rate of charge for light is paise 20 for the first 40 kilowatts and paise 22 for the second 80 kilowatts. Determine the total charge, in rupees, if 90 kilowatts are consumed.
2. Watt Problem. An electrical apparatus is rated at 220 volts and 5 amperes. Determine how many watts the apparatus is rated at.
3. Voltage Problem. Design a series circuit containing four pieces of electrical apparatus. Determine how many volts will be required to operate the circuit satisfactorily.
4. Current Problem. Design a parallel circuit containing four pieces of electrical apparatus. Determine how many amperes will be required to operate the circuit satisfactorily.
5. Fuse Problem. A 500 watt refrigerator, 150 watt exhaust fan and 300 watt air cooler are connected to a branch circuit. Determine the correct size fuse for this branch circuit.

- Wholesale Electric Dealers. *Adarsh Electrical Catalogue* Delhi, 1963.
- Buban, Peter and Schmitt, Marshall L. *Understanding Electricity and Electronics* New York : McGraw-Hill Book Company, Inc., 1963
- Central Water and Power Commission (Power Wing). *Rural Standards Construction Manual*, New Delhi : Ministry of Irrigation and Power, 1960.
- Central Water and Power Commission (Power Wing). *Rural Standards Construction Manual, Designs-General*. New Delhi : Ministry of Irrigation and Power, 1958.
- Crispin, Frederic S. *Dictionary of Technical Terms* Milwaukee, Wisconsin : Bruce Publishing Company, 1946
- Gerrish, Howard H. *Electricity*. Chicago : Goodheart-Wilcox Co. Inc , 1961.
- Indian Standards Institution. *Indian Standard Code of Practice for Electrical Wiring Installations (Systems Voltage not Exceeding 650 Volts)*. IS: 732-1963. New Delhi.
- Indian Standards Institution. *Indian Standard Glossary of Terms for Electric Cables and Conductors*. IS: 1591-1960. New Delhi.
- Indian Standards Institution. *Indian Standard Specifications for Carriers and Bases in Rewirable Type Electric Fuses up to 650 Volts*. IS: 2086-1963. New Delhi.
- Indian Standards Institution. *Indian Standard Specifications for Rubber-Insulated Cables and Flexible Cords for Electric Power and Lighting*. IS : 434-1953. New Delhi
- Indian Standards Institution. *Indian Standard Specifications for Three-Pin Plugs and Socket Outlets*. IS: 1293-1958 New Delhi.
- Oldfield, R.L. *The Practical Dictionary of Electricity and Electronics*. Chicago : American Technical Society, 1960.
- Steinberg, William B. and Ford, Walter B. *Electricity and Electronics*. Chicago: American Technical Society, 1961.



Working Models of Electric Hot Plates





Working Model of Electric Hot Plate

Unit 2

HOT PLATE

1. TRANSFORMING ELECTRICAL ENERGY INTO HEAT ENERGY

SINCE THE beginning of time, man has used fire as a source of heat. He has, for example, used fire to heat his home, cook his food, bake clay and forge metal. Three major problems arising from the use of fire for heat are :

- (1) To have a readily available source of fuel,
- (2) To provide some method of controlling heat intensity ;
- (3) To eliminate the potential dangers inherent in the use of fire.

The major sources of fuel for fire have been dung, wood, coal, kerosene, and gas. The heat has been controlled to some extent by the use of various types of fire-places and stoves, with the draught controlled through the use of damper and flue arrangements. Even with the exercise of extreme safety precautions, the hazards from a live flame under certain conditions can be very dangerous.

1.1 Applications of Electric Heat

The discovery of electricity, and its applicability as a source of power for heat, has provided man with the opportunity to use it to advantage in many situations. For example, the electric heater for heating the home in winter, and

the electric stove for cooking, are odourless, clean and efficient, and with approved types of installation, very safe. Industry uses electricity as a source of heat in situations where speed, accuracy of control and cleanliness are very important. For example, electric kilns are used for firing ceramic ware, electric heat lamps are used to bake paint on automobiles, and electrically heated drums are used to dry ink on high-speed automatic printing presses. The industrial potential of electric power as a source of heat appears to be endless as the ingenuity of man develops new concepts of application.

1.2 Principle of Electric Heat

An electric heating element when cold, looks like an ordinary piece of wire. However, when power is supplied it glows a bright orange-red colour and gives off intense heat.

The change of electric energy into heat energy is based on the principle of resistance. We know that a good conductor of electricity, such as a copper wire, carries the flow of electric current with little resistance. Therefore, it is considered a good conductor of electricity. A good conductor of electricity produces little heat. A poorer conductor of electricity, such as resistance wire, resists the flow of electric current. Therefore, it is considered a poor conductor of electricity. However, this poorer conductor of electricity, in its resistance to the flow of electric current, causes the electric energy to be given off in the form of heat energy.

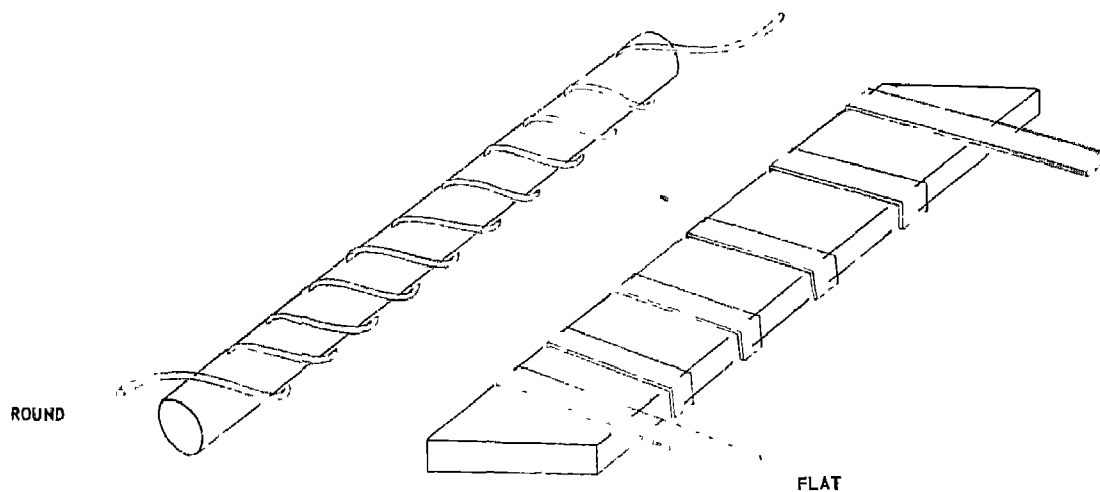


Fig. 2.1.A Resistance Wire Shape

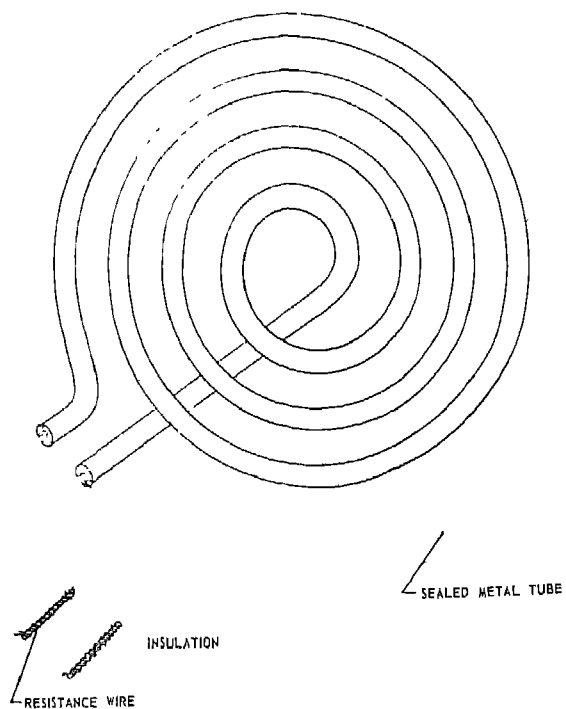


Fig. 2.1.B Sealed Heating Unit

Wire is rated according to its current-carrying capacity. The higher the current-carrying capacity the better its ability to conduct electricity. Therefore, it is usually stated that as the ability of a wire to conduct electricity increases, the resistance decreases. It should also be recognized that the inverse of this is true. As the ability of a wire to conduct electricity decreases, the resistance increases. Or, it may be stated that as the resistance in a wire increases the ability to conduct electricity decreases. It is this resistance to the flow of electricity that causes the wire to get hot enough to glow orange red in colour and give off heat. Thus, *electric energy* is transformed into *heat energy*.

One might compare riding a bicycle to electrical resistance and how it causes a heating element to give off heat. For example a bicycle can coast downhill with no resistance. The rider because he exerts no physical effort is cool. However, a bicycle rider pumping uphill meets increased resistance and there by exerts physical effort that gives off heat energy. Any variations in between, such as steepness of the hill and physical effort expended will affect the amount of heat energy given off. In comparing electricity to a man riding a bicycle, a good conductor of electricity allows the electricity to flow freely with no resistance and, therefore, remains cool, just as the rider of a bicycle coasting downhill. However, a poor conductor, because of increased resistance, restricts the flow of electricity, which causes, as with the rider of the bicycle pumping uphill, excess electrical energy to be given off as heat energy. Also, any variations in between, such as ampere and voltage fluctuations, and resistance change, will affect the amount of heat energy given off. Therefore, the rated conductance capacity of a wire and its resistance to the current flow passing through it, causes electric energy to be given off in the form of heat energy.

2. HEATING ELEMENTS

2.1 Types of Heating Elements

The most common and least expensive heating

element in use today is the type with exposed resistance wire. The standard shape of the resistance wire used in these heating elements, as shown in Fig. 2.1. A, is either round or flat. The exposure of the resistance wire to air and moisture shortens the life of the wire and causes it to burn out.

In some of the newer electrical appliances, as shown in Fig. 2.1. B, the resistance wire is protected by placing it inside a hollow metal tube. The resistance wire is insulated from the hollow metal tube, and the ends of the tube are sealed. Then the heating element unit is formed into the desired shape. These protected heating element units seldom burn out because they are not exposed to air or moisture.

2.2 Resistance Wire

Heating element wire, because it needs a high resistance to electricity, is generally made from metals like chromium, iron, and nickel. Two or more of these metals are melted together to form an alloy called *resistance wire*. The composition of resistance wire may vary; however, in general it is 60 per cent nickel, 15 per cent chromium, and 25 per cent iron. The combination of these metals, when used for resistance wire, provides a high resistance that enables the wire to become red hot without melting or burning.

The electrical ratings of resistance wire varies according to the combination and percentage of metals in any given wire. Therefore, each manufacturer should provide in written form electrical data for the particular wire manufactures. Six basic types of data should be available for determining the construction needs of an electric heating element.

TABLE XI
RESISTANCE WIRE DATA FOR 230 VOLTS
80 Per cent Nickel and 2 per cent Chromium

Watts	Approximate Amperes	Resistance In Ohms	B & S Wire Size	Diameter Inches	Approximate Length in Feet	Ohms per Foot
100	0.435	494	33	0.0071	38.3	12.90
200	0.87	247	32	0.0008	24.4	10.16
300	1.3	160.47	31	0.0089	16.9	8.206
400	1.73	123.52	29	0.0113	24.2	5.09
500	2.17	98.82	27	0.0142	30.6	3.228
600	2.6	82.35	26	0.0159	32	2.571
700	3.04	70.58	25	0.0179	34.8	2.029
800	3.48	61.77	25	0.0179	30.7	2.020
900	3.9	54.90	24	0.0201	34.2	1.609
1000	4.35	49.41	23	0.0226	38.7	1.273
1100	4.8	44.92	23	0.0226	35.0	1.272
1200	5.52	41.17	22	0.0253	38	1.017
1300	5.65	38.00	21	0.0285	47.5	0.8002
1400	6.10	35.30	20	0.032	55.7	0.6347
1500	6.54	32.94	19	0.0359	66.0	0.5015

- | | |
|---------------------------|---|
| (1). <i>Watts</i> | The rated number of watts for resistance wire of a particular size. |
| (2). <i>Wire Size</i> | The recommended gauge of the resistance wire for a heating element of specific size. |
| (3). <i>Amperes</i> | The amount of current flow through a heating element of specific size. |
| (4). <i>Resistance</i> | The amount of resistance in ohms, for a heating element of specific size. |
| (5). <i>Wire Length</i> | The approximate length of resistance wire, in feet, for a heating element of specific size. |
| (6). <i>Ohms Per Foot</i> | The approximate ohms per foot for a heating element of specific size. |

All these six factors are variables that affect the construction and satisfactory operation of a heating element.

An example of manufacturer's resistance wire data is included for Study. The data in Table XI are based upon 230 volt resistance wire composed of 80 per cent nickel and 20 per cent chromium.

2.3 Insulation

Electric heating elements require a type of insulation that is resistant to both the flow of electricity and extreme high heat. Usually they are formed from such substances as asbestos, mica, or high temperature fire-clay. The shape of the heating element determines whether the insulation can be cut from a solid type of sheet insulation, or can be formed from a mouldable type of insulating material.

3. HOT PLATE EXPERIMENT

MATERIALS

3.1 Clay

Three styles of ceramic bases are suggested for the hot plate.

(a) A completely self contained unit, as shown in Fig 3.1.A, made from a high temperature fire clay.

(b) A two piece unit, as shown in Fig. 3.1.B, incorporating a commercially made ceramic heating element insulator mounted on top of a low temperature fire clay base.

(c) A two-piece unit, as shown in Fig. 3.1.C, incorporating a commercially made ceramic heating element insulator mounted on top of a commercially made kunda (large flat bowl).

Clay provides two outstanding advantages for the electrical system of the hot plate. First, it is a non-conductor of electricity and makes a good insulator for the entire electrical system. Second, it is a heat resistant material and has the advantage of withstanding the high operating temperatures required of a hot plate.

The self-contained ceramic base must be sculptured or moulded from a good quality high temperature fire clay. The heating element, which is recessed in the top, becomes an integral part of the base unit. Therefore, when the heating element is turned on, the top of the base becomes red hot. To withstand this extreme heat a high temperature fire clay must be used.

Both of the two-piece unit ceramic bases are made from low temperature fire clay. The first style is sculptured or moulded, except for the flat top, similar to the self-contained unit. The second style is made on a potter's wheel in the shape of a kunda or purchased from the market.

It is possible to use a low temperature fire clay for the two-piece unit base, because the commercial ceramic heating element insulator is made from a high temperature fire clay that will withstand the high heat. In mounting the two-

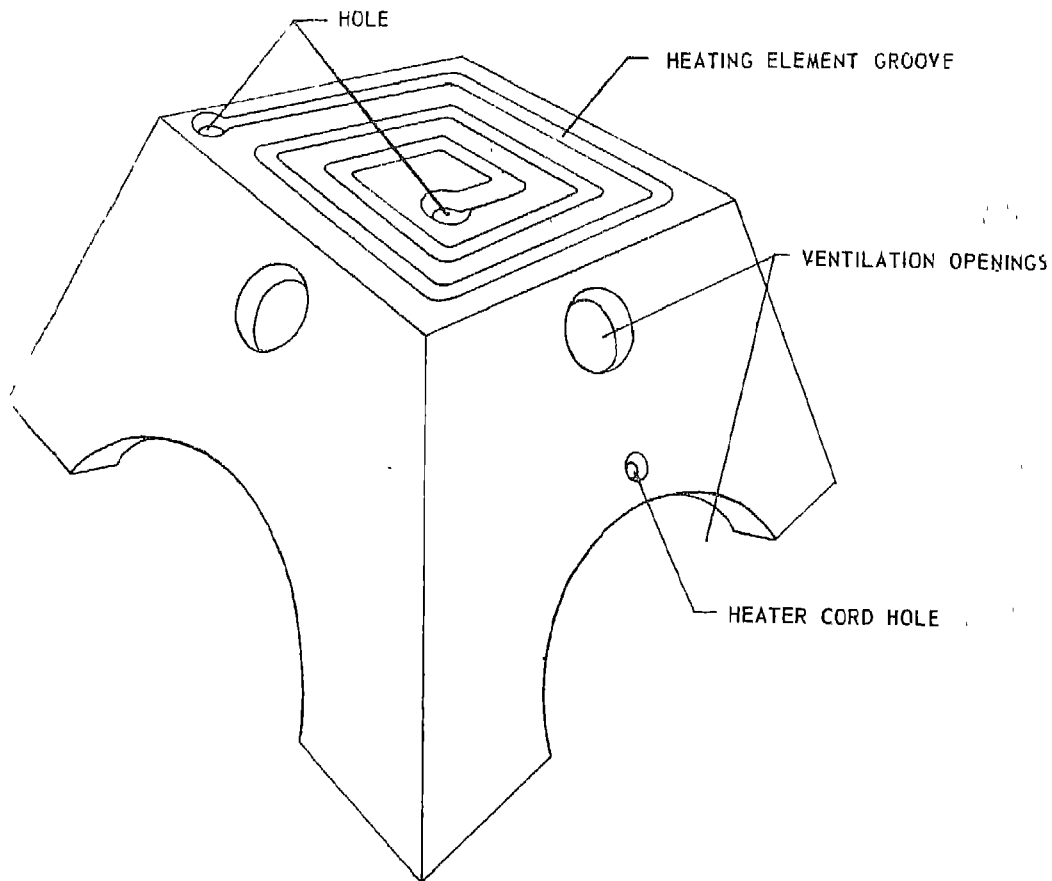


Fig. 3.1 A. Hot Plate Base

piece units, an air space, which acts as an insulator, is left between the commercial ceramic heating element insulator and the low temperature fire clay base. Therefore, the low temperature fire clay base is capable of withstanding the amount of transferred heat from the heating element unit mounted above.

3.2 Wire

The wire used for the heating element must be resistance wire. The resistance wire selected for this size hot plate is 1000 watts, No. 24. A

wire of any number between 20 and 24 gauge will work. However, as the gauge number of the resistance wire changes, the length of the resistance wire needed must also change.

When buying resistance wire, be sure that it has been wound on a wood, metal, or plastic reel. To prevent kinks and bends while using, slip the reel of wire on a rod and allow it to run off freely.

Heater cord of good quality should always be used with heating appliances. An approved

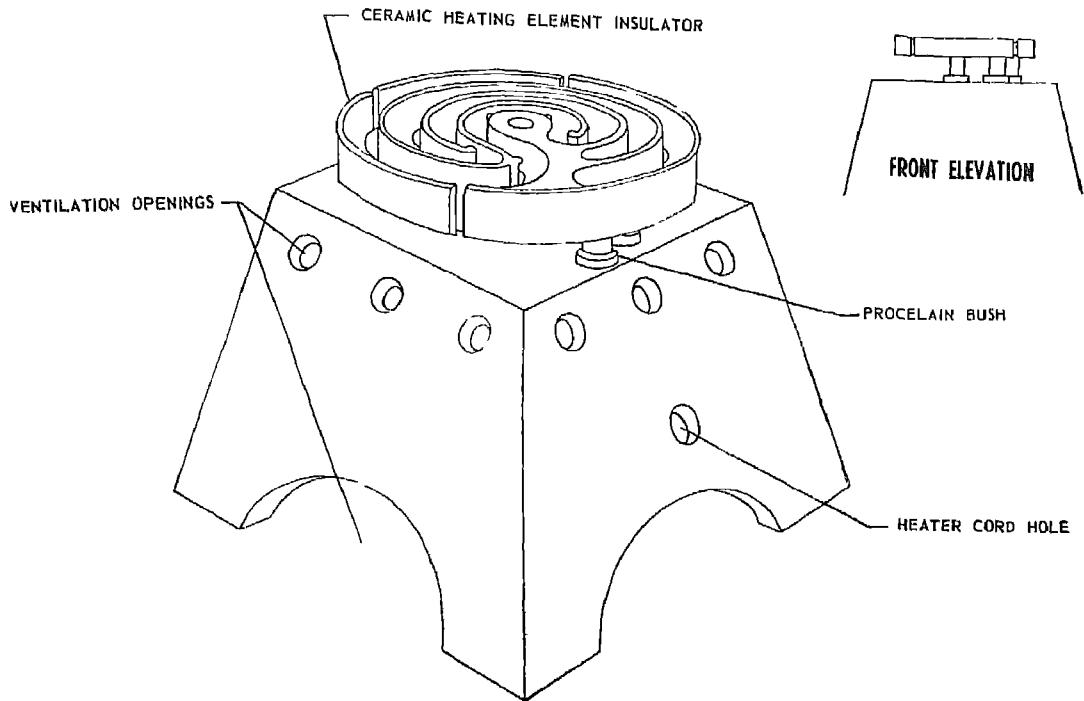


Fig. 3.1:B Sculptured or Moulded Two Piece Hot Plate Unit

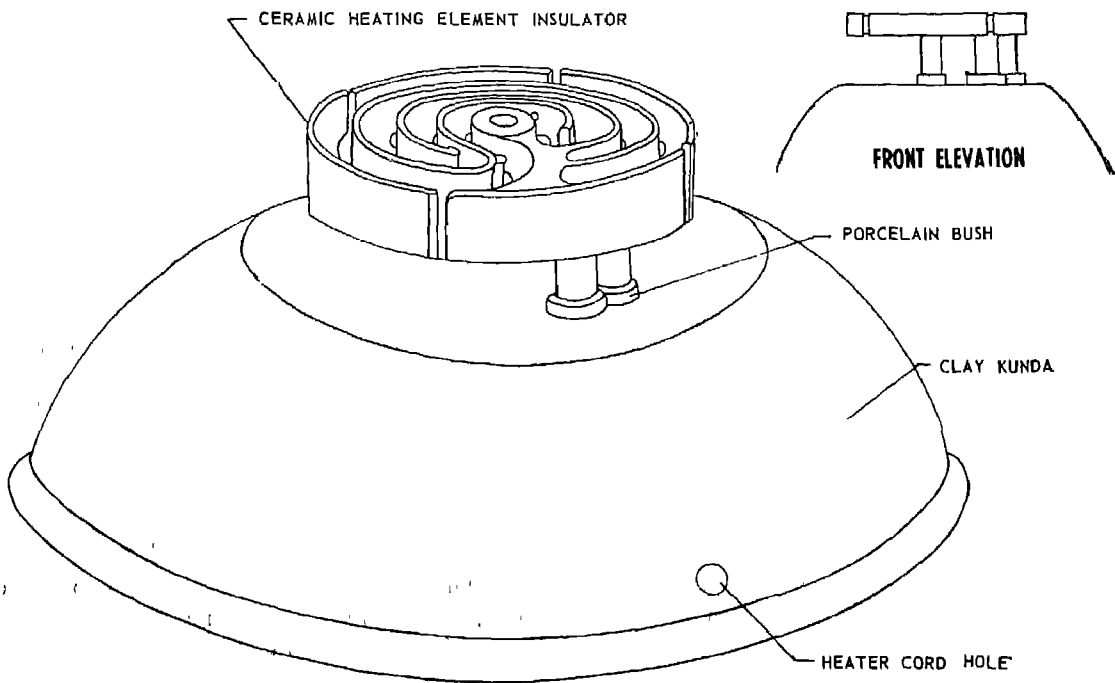


Fig. 3.1.C Two Piece Hot Plate Unit Made on Potters Wheel

heater cord, as shown in Fig. 3 2 A, consists of twisted flexible wire coated with rubber, which is then wrapped in asbestos and sheathed in a cotton, rayon, or silk braided outside cover.

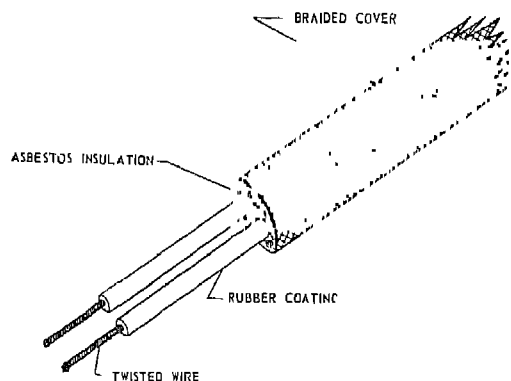


Fig. 3 2 A Heater Cord

3.3 Hardware Fasteners

Brass nuts and bolts, such as round head $3/16" \times 2"$, are very suitable for connecting the heating element to the power supply in a recommended terminal arrangement

Brass washers, $3/16"$ inside diameter, should be used to ensure proper tightening for good electrical connections.

Brass bolts, nuts, and washers are recommended, in preference to steel, because they resist corrosion.

3.4 Attachment Plug

Select a good quality two or three pin attachment plug to connect to the flexible heater cord. A conventional three-pin attachment plug with an earthing contact is required on all metal base hot plates; however, the use of fire clay for the hot plate eliminates shock hazard and the necessity of making an earthing contact.

ELECTRIC HOT PLATE EXPERIMENT

PROCEDURE

3 5 Base

Self Contained Base

Sculpture or mould the hot plate base, as shown in Figure 3.1.A. The approximate measurements are, top $6"$ square, base $8"$ square, and height $5"$. The inside of the hot plate base is hollowed out, leaving the top and sides about $1/2"$ thick. The groove to receive the heating element is approximately $3/8"$ wide, $3/8"$ deep, and $36"$ long. The groove laid out in a rectangular shape, should evenly cover the entire top area. At each end of the heating element, recess an area large enough to hold a washer. In the centre of this area make a hole all the way through the top, large enough for the heating element electrical connector bolts to be fixed.

Adequate ventilation for the hot plate can be provided by cutting a large opening on each side at the base line and a smaller opening directly beneath the top Figure 1.3 A. The cool air coming in at the base openings will circulate through the hollow base, become hot, and escape out of the top openings. Under normal operating conditions a hot plate is adequately ventilated if the table top directly beneath it does not exceed 42°C .

Near the base line, on one side, make a $1/2"$ hole for insertion of a flexible heater cord.

It should be pointed out that clay in its drying and firing process shrinks approximately 15 per cent. The measurements given for this hot plate base include the 15 per cent shrinkage; therefore, the hot plate in its finished form will be slightly smaller.

Two piece Unit Base

The sculptured or moulded two piece unit base, as shown in Figure 3.1 B, is made similar to the self-contained unit base except for the flat top.

Mounting and wiring holes, for the ceramic heating element insulator, should be made in the top while the clay is still soft. The holes should be made a little larger than the diameter of the connector bolts. This will ensure, after shrinkage, that the mounting and wiring holes of the two pieces match.

A commercial kunda that has been made on a potter's wheel, as shown in Figure 3.1 C, may also be used for the base. Select a good kunda, with no cracks, that has a flat rim and base. The flat rim and base are necessary because when the kunda is turned upside down on the rim it should not rock, and the bottom should be flat to ensure level mounting of the ceramic heating element insulator.

Centre the ceramic heating element insulator on the bottom of the kunda. Mark through the holes of the ceramic heating element insulator, on the bottom of the kunda the exact position of the centre mounting hole and the heating element connector holes. Also mark on the side of the kunda the position where the heater cord is to enter.

The holes can be made through the kunda by grinding them with a piece of brass tubing. Select a piece of brass tubing the size of the connector bolts and the heater cord. Place the brass tubing in a drill or twirl it by hand. The end of the brass tubing grinds its way through the hard clay. Make a little ring of soft clay around the area where the hole is to be ground. Keep the area where the hole is to be ground filled with water. The water mixes with the hard clay as it is ground and forms what is known as a *grinding compound*. When this harsh abrasive material is forced under the tip of the brass tubing it actually grinds its way through the hard clay kunda. The water also tends to dissipate the heat generated by the friction of the revolving brass tubing.

3.6 Heating Element

The resistance wire selected for this heating

element is No. 24, 1000 watts. Approximately 32 feet of wire is required to wind the heating element

Certain variables affect the selection of resistance wire for a heating element. The electrical data on resistance wire such as the watts, wire size, amperes, resistance, ohms per foot, and length, are helpful in determining heating element design. By the use of the electrical formulae $E=I \times R$ and $W=E \times I$ (E =Volts, I =Amperes, R =Resistance, W =Watts), heating elements sizes can be determined.

For ease of calculation a heating element of 1100 watts has been selected as an example of how to determine the length of the resistance wire needed when the wire data are known. The formulae given with computations show how to solve for an electrical unknown when two factors are known.

Resistance Wire Data

E	=	220 Volts
I	=	5 Amperes
R	=	44 Ohms Resistance
W	=	1100 Watts
OPF	=	1.4 Ohms Per Foot

$E=I \times R$ Formula

	$E = I \times R$	$I = \frac{E}{R}$	$R = \frac{E}{I}$
		$\frac{220}{44}$	$\frac{220}{5}$
$E=5 \times 44$		$I=5$	$R=44$
$E=220$			

$W=E \times I$ Formula

	$W = E \times I$	$E = \frac{W}{I}$	$I = \frac{W}{E}$
		$\frac{1100}{5}$	$\frac{1100}{220}$
$W=220 \times 5$		$E=220$	$I=5$
$W=1100$			

The length of the resistance wire is determined by dividing the total resistance by the ohms per foot.

$$\text{Length} = \frac{R}{\text{OPF}}$$

$$L = \frac{44}{1.4}$$

$$L = 32 \text{ Feet}$$

If all the heating wire data are not available, the correct length of resistance wire can be determined by experimentation. At least the voltage and watts for a given size of resistance wire should be available on the face of the reel. Then determine, by the formula $W = E \times I$, the amount of amperes required for that specific size wire. Design testing apparatus similar to the one shown in Figure 3.6.A. The uprights, fastened to a

sturdy wooden base have a 3 foot clearance between centres. Nails, covered with ceramic insulators are spaced a few inches apart. Approximately 50 feet of resistance wire can be strung on the ceramic insulators. Connect an ammeter in series to one end of the resistance wire. Connect the other end of the 220 volt lead, with a spring clip, to the opposite end of the resistance wire. Turn the voltage on and read the ammeter. If the ammeter does not read the correct amperes, shut off the voltage and move the spring clip along the wire to a new position. Turn on the voltage and read the ammeter. Continue this process until the correct ammeter reading is obtained.

It should be noted as the spring clip is moved along the wire and the ammeter reading changes, the resistance wire first shows signs of heat by

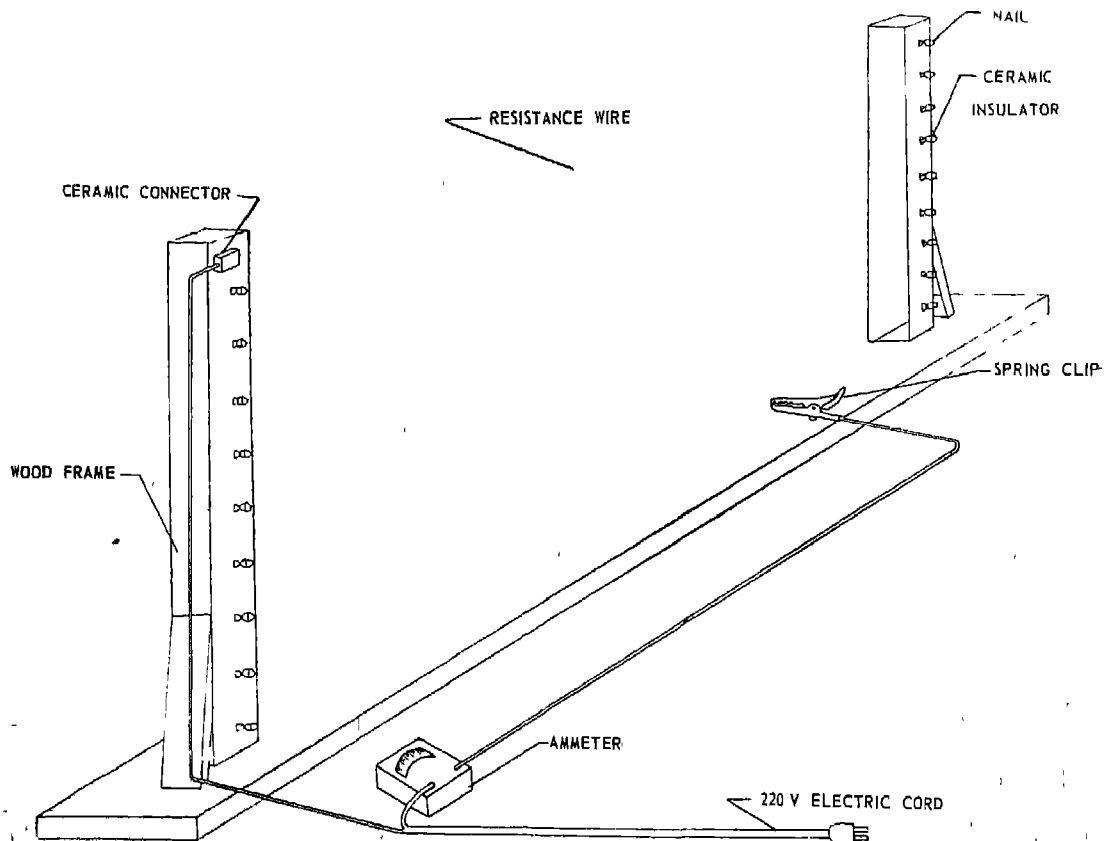


Fig. 3.6.A. Resistance Wire Testing Apparatus

stretching. This proves the point that heat expands metals. Notice that if the wire is permitted to cool it contracts to its original length. The resistance wire also begins to produce a soft red glow and give off heat. At this point the temperature range is approximately 670°C . When the correct ammeter reading is reached, the wire colour gives off a bright orange—red glow, and reaches the most efficient operating temperature of approximately 980°C . The experimental method, even though an ammeter is not available for a meter reading, by observation of the bright orange colour is accurate enough to determine the proper length of the resistance wire.

3.7 Winding Heating Element

Resistance wire in a heating element should be precision—wound. Accuracy of the winding technique produces an evenly wound element that does not 'short out'. Each time one coil touches another it changes the resistance in the wire just as if the wire was being shortened.

Resistance wire is quite soft and can be formed into a coil that will hold its shape. A simple friction hand winding apparatus, as shown in Figure 3.7 A, will wind a perfect coil. Place one end of the correct length of resistance wire through the guide hole and into the slotted end of the rod winder. Fix the rod winder in the apparatus so that the resistance wire touches the head stock of the winding apparatus. Tighten the wing nuts enough to produce friction on the winding rod. Wind the heating element by turning the handle of the rod winder. The heating element winds automatically as the revolving rod drives the resistance wire snugly against the head stock.

Remove the wound heating element from the winding apparatus and slip it off the winding rod. Bend loops, as shown in Figure 3.7.B, at each end of the heating coil. The loops should be made so that they will fit tightly around the bolts where the electrical connection is made.

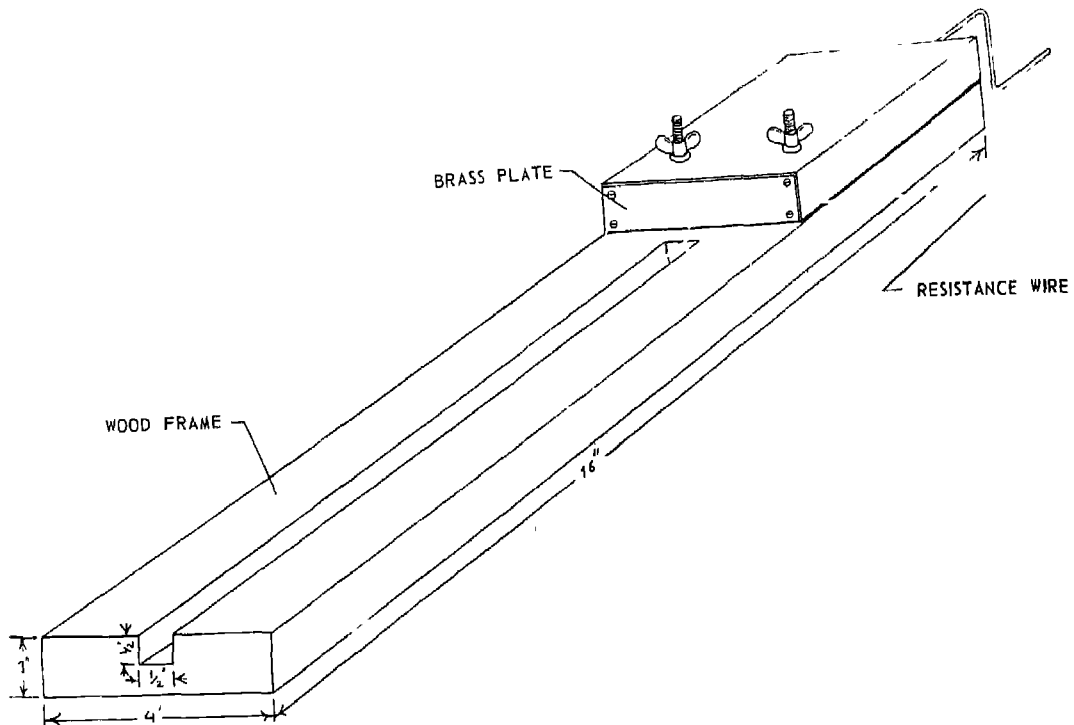


Fig. 3.7.A Heating Element Winding Apparatus

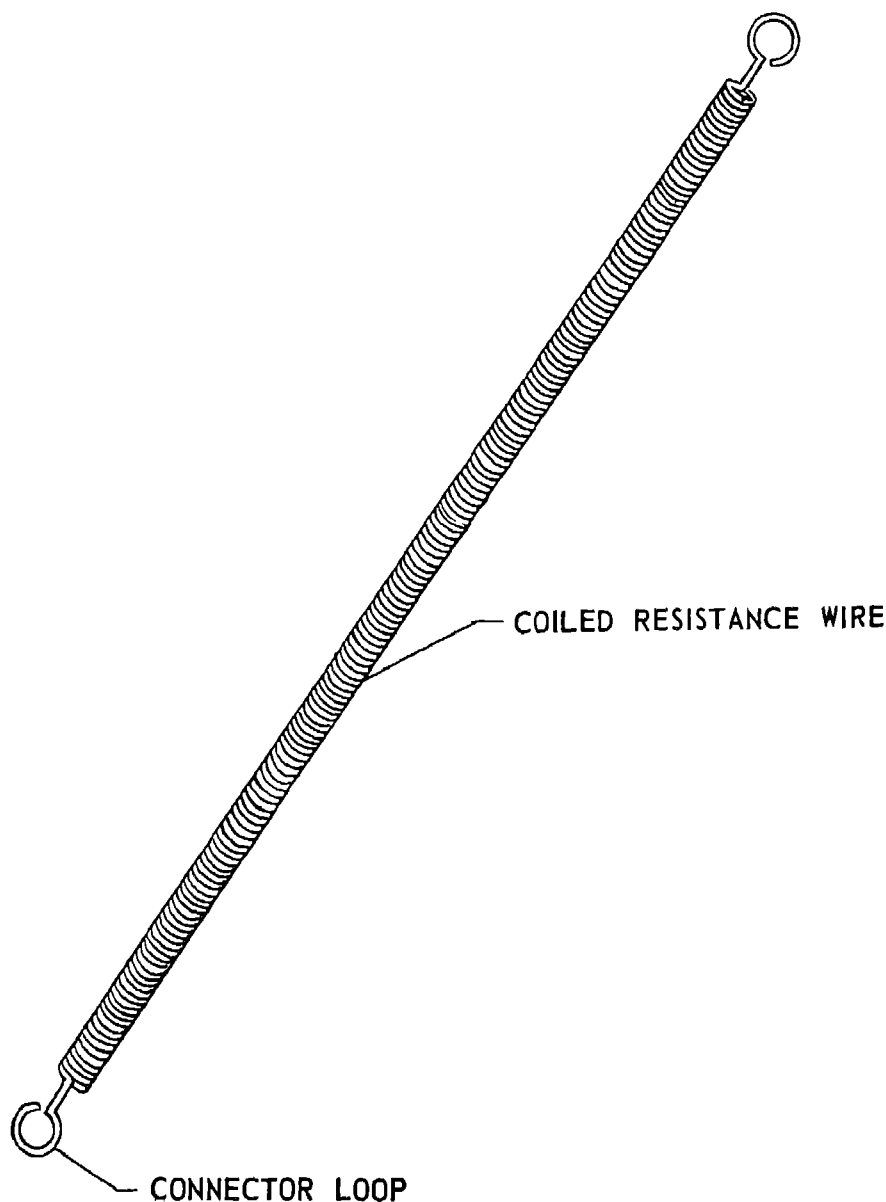


Fig. 3.7 B Heating Element

3.8 Hot Plate Assembly

Stretch the heating element evenly by grasping it at both ends to the approximate length of the heating element groove in the top of the hot plate. Again, it is important to stress the electrical advantage of an evenly stretched heating element. Uneven stretching can cause a short

circuit that will reduce the life of the heating element.

Place one loop of the heating element between two washers on an electrical connector bolt. Slip the bolt through the centre mounting hole, as shown in Figure 3.8 A, of the hot plate base. Place a washer and nut, from the underside of the hot plate base, on the connector bolt. Lay the heat-

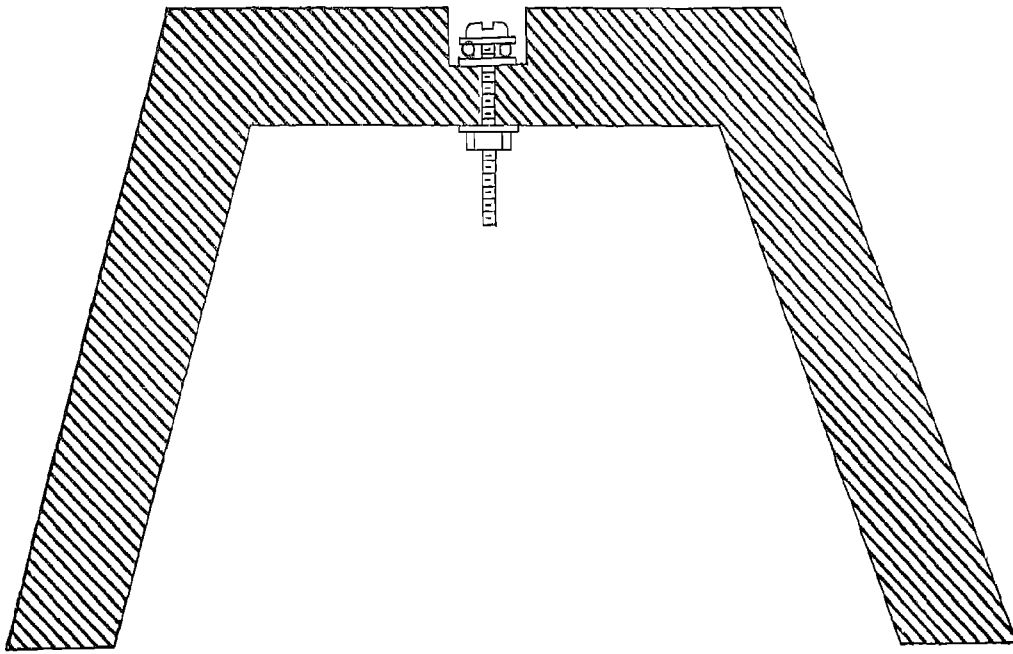


Fig. 3.8.A Cross Section View of Heating Element Connection

ing element in the hot plate groove and connect the other loop through the outer hole in the same manner. Tighten both electrical connections securely. Good electrical connections are necessary because of the great amount of expansion and contraction caused by the intense heat. Poor electrical connections cause arcing and burning which shortens the life of the heating element.

Remove approximately 4" of the braided outside cover from one end of the heater cord. Strip approximately 1" of insulation from each flexible wire. Be careful not to cut any of the strands in the flexible wire. Each strand removed actually decreases the size of the wire and reduces the rated electrical carrying capacity of the wire. Twist the strands of the bared ends of the flexible wire tightly together. Form a loop in each wire the size of the electric connector bolts, as shown in Figure 3.8.B, and wrap the ends tightly around the main strands. Place a washer on each side of the wire loops and slip them over a connector bolt. Thread a nut into each connec-

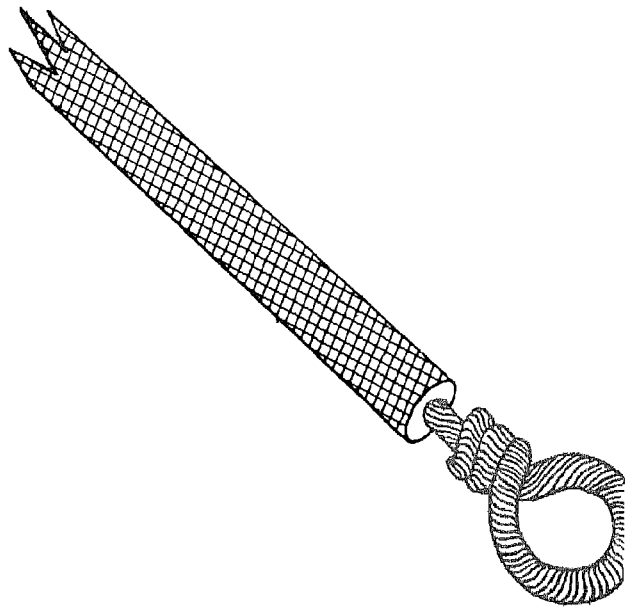


Fig. 3.8.B Heater Cord Connector Loop

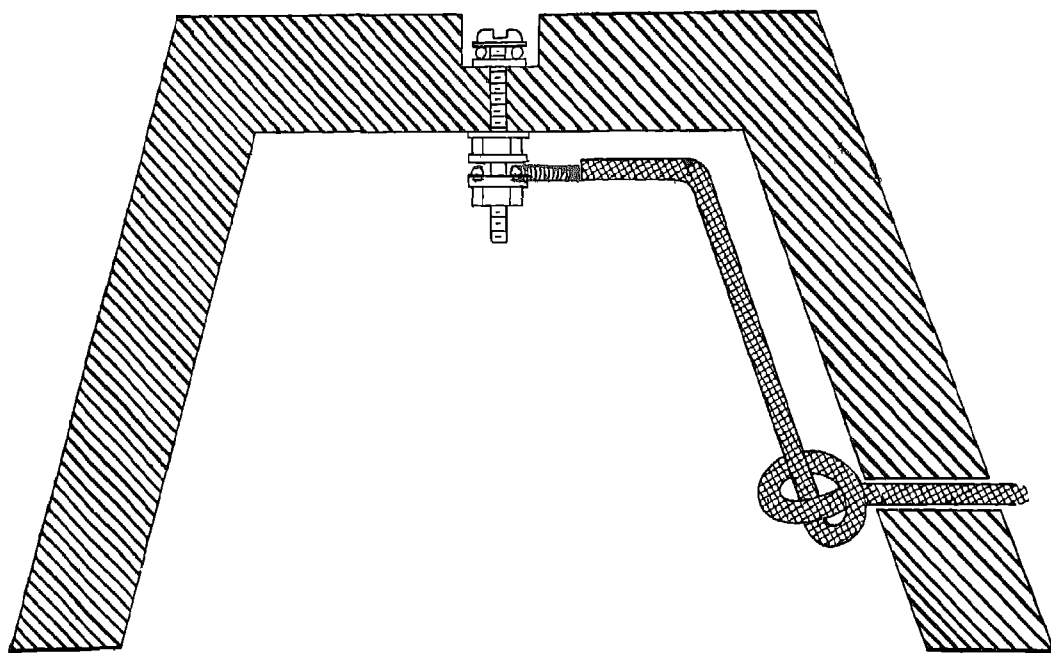


Fig 3.8.C. Cross Section View of Heating Element Connection

tor bolt as shown in Figure 3.8.C, and tighten them securely. Tie a knot, approximately 6" from the end, in the heater cord wire. Slip the heater cord, from the inside out, through the heater cord hole in the side of the base. The knot, positioned where the heater cord leaves in hole in the base, ensures that not undue pressure can be applied to the electrical connector terminals in the event the heater cord is inadvertently pulled.

Remove approximately 1 1/2 of braided outside cover from the opposite end of the heater cord. Strip approximately 1/4" of insulation from each flexible wire. Be careful not to cut

any strands in the flexible wire. Place the cover of the two-prong attachment plug on the heater cord. Tie an *Underwriters' knot*, as shown in Unit-1, Figure 5 4 C, in the two electrical wires. The underwriters' knot prevents the wires from being pulled at the terminal posts. The knot, instead of the wire, takes the strain when the cord is improperly pulled from an electrical socket. Twist the strands of the bared ends of the wire tightly together. Place the ends of the wires in the terminal posts of the attachment plug, as shown in Figure 3.8.D, and tighten the clamping screws securely. Screw the cover and base of the attachment plug together.

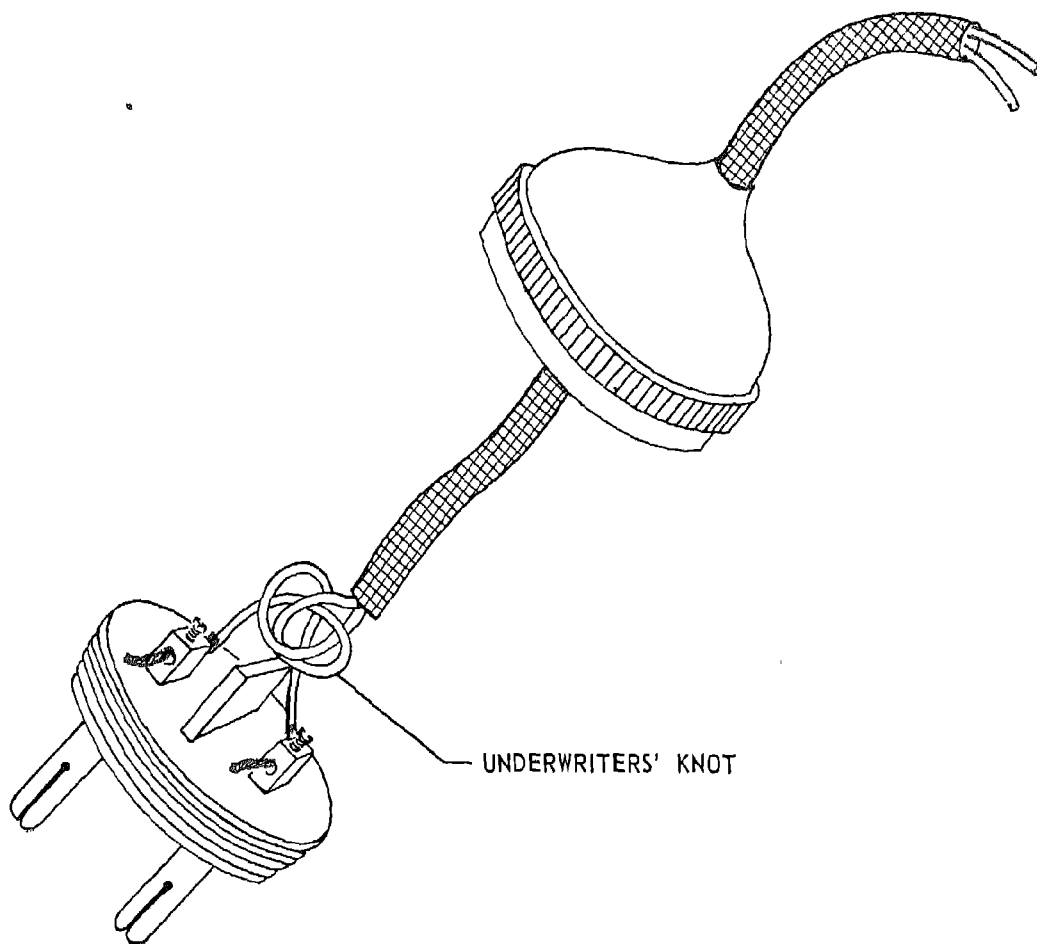


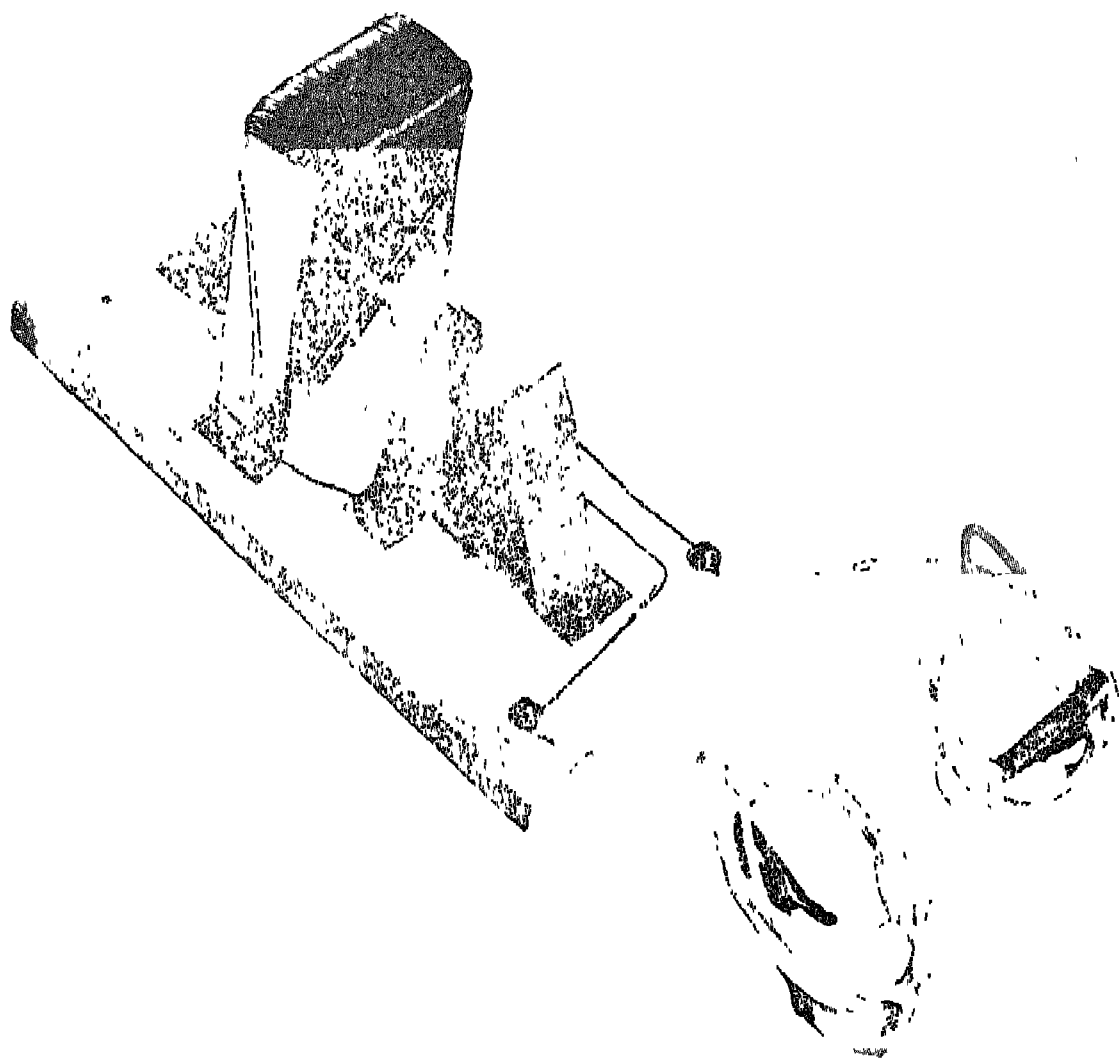
Fig. 3.8.D. Two Pin Attachment Plug

STUDY QUESTIONS

The Heating Element Unit contained many important ideas and practices of electricity that you should understand. The following questions have been listed as types that your instructor will use for internal grading. Therefore, review this unit well until you are able to answer all the questions easily and correctly. If you are unable to understand the questions or find the answers, please see your instructor for help.

ESSAY QUESTIONS

Essay questions should be designed to provide each student with the opportunity to express in writing, technical information on a limited subject. Each student can be assigned a different topic, or the same topic. The advantage of different topics is that it will provide the teacher with a broader reaction to all of the materials studied.



Working Model of the Electric Motor

Unit 3

ELECTRIC MOTOR

1. TRANSFORMING ELECTRICAL ENERGY INTO MECHANICAL ENERGY

SINCE THE beginning of time man has used muscle power as a source of mechanical power. He used his own muscles entirely in the beginning and then later, as civilization advanced and the need for more power increased, he added the use of animal power. In his continual search for ways in which to do his work easier, better and faster, man has now added the use of electric motor power.

1.1 From Man to Electric Power

Man, as shown in Figure 1.1.A, has always drawn water from a well with muscle power by the use of a rope and bucket. Then, with a water wheel bucket arrangement, he added animal power. Today the modern method employs the use of a water pump driven by an electric motor. Man, then, is actually using electricity to replace muscle power in an easier, better, and faster way, because, it can be shown by quantity that the bucket can draw 4 1/2 litres in one minute in comparison to the electric driven pumps continuous flow of hundreds of litres per minute. An electric motor then, doing the same kind of work that muscle power does, may be defined as a machine that transforms electrical energy into mechanical energy.

Electric motors of all types and sizes are used in thousands of ways in home and industry. Electric motors are used as a source of mechanical power for: fans—to circulate cooling air in the home ; refrigerators—to keep food cold ; washing machines—to clean clothes ; automobiles—to start

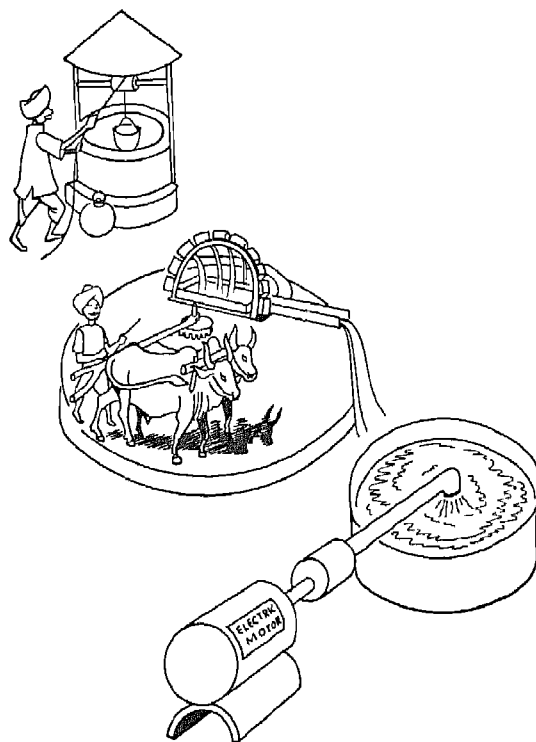


Fig. 1.1.A Power : Man—Animal—Electric

the engine running, industry—to run woodworking and metal working machines. Today, in technically advanced countries, electric motors furnish more than 90 per cent of the mechanical power.

1.2 Basic Principle of Operation

The electric motor works by means of magnetism. The principle of attraction and repulsion of magnetic poles causes the change of electrical energy into mechanical energy. The actual change of the electrical energy into mechanical motion is due to the internal structure of the motor. The housing, which usually does not move because it is rigidly mounted, has electromagnets that attract and repel fastened to its sides. An electromagnet that can rotate by attraction and repulsion is also suspended on bearings through the centre of the motor housing. Current passing through both the rigidly mounted electromagnets and the electromagnet that can rotate, sets up between themselves a strong magnetic attraction and repulsion force. Therefore, the electromagnet that can rotate starts to move. Because the current that passes through an electromagnet can be controlled, the attraction and repulsion force of each magnet (north and south pole) can be constantly changed. Technically this means that an electric motor is so designed there are many controlled electromagnetic forces that which attract and repel each other. Therefore, once the electromagnet that can rotate starts to move by attraction and repulsion there are a series of electromagnetic forces that continue to constantly attract and repel and thereby keep the motor running.

1.3 Name Plate Data

A name plate, as shown in Figure 1.3.A, is usually fastened to the outside of the motor housing and gives specific details pertaining to the operation of the motor. The name plate should list the manufacturer's name, model number,

horsepower, revolutions per minute, voltage, cycle and amperes of the motor.

The manufacturer's name, based upon the company's reputation, should be an indication on

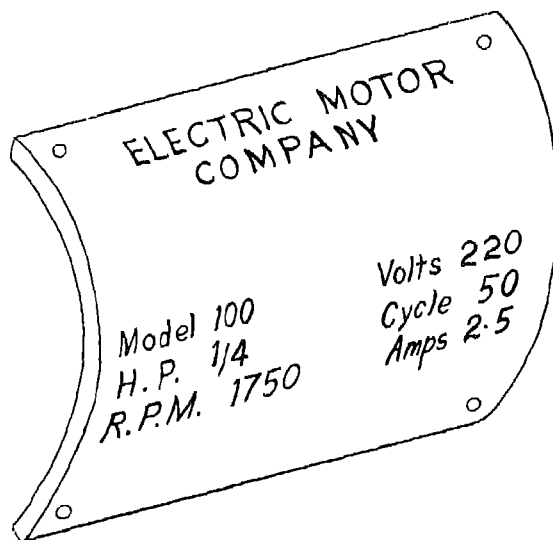


Fig. 1.3.A Motor Name Plate

the reliability of the motor. It is considered a good consumer practice to purchase a motor from a reputable electric company.

The model number provides the opportunity to determine the construction quality of the motor. The manufacturer's specifications, for each model number, should be available in some type of a brochure or catalogue.

Horsepower (H.P.) is the rating, in terms of a mechanical unit of power, that determines the size of an electric motor. A horsepower, as shown in Figure 1.3.B, is the amount of effort required to lift a weight of 550 pounds a distance of one foot in one second of time. In terms of electricity one horsepower is equal to 746 watts of electric power. Most of the motors used in a home and by light industry are rated a fractional-horsepower. This means that their size is less than one horsepower. Powerful motors used for heavy industrial work may have power ratings of from one to a 1000 horsepower or more.

Revolutions per minute (R.P.M.) refers to the number of times the motor shaft revolves in

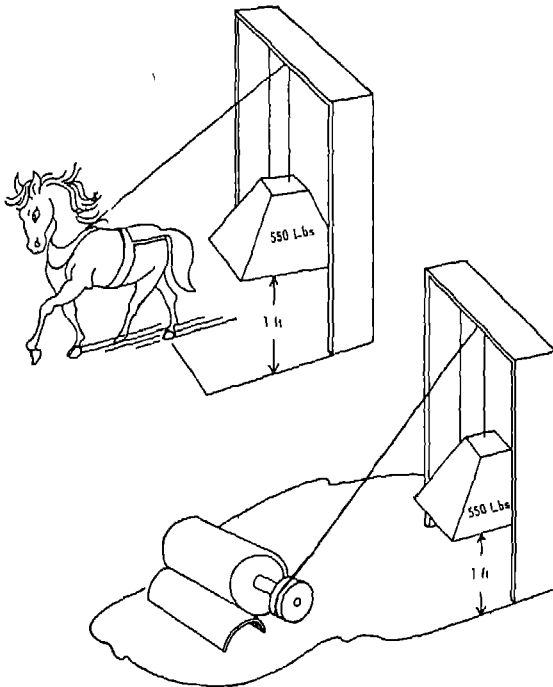


Fig. 1.3 B. Horse Power Rating
550 lbs. Lifted 1FT. in One Second

one minute. Motors are manufactured, depending upon the type, that run a few hundred R.P.M., a few thousand R.P.M., or many thousands of R.P.M.'s.

Motors are usually designed to operate on either direct current (DC) voltage, or alternating current (AC) voltage. However, some motors, depending upon the type, are designed to operate on either DC or AC voltage. *Direct current* (DC) voltage, as in a battery, is current that flows only in one direction. While *alternating current* (AC) reverses in direction at rapid, regular intervals.

Cycle is the number of times that alternating current (AC) makes a complete cycle (reverses in direction) in one second. This change in direction is called alternating. The alternating current produced by India power stations is

usually 50 cycle. A motor name plate stamped 'Cycle 50' means that it is designed to operate efficiently on Indian 50 cycle current. Actually, current travels 50 times in one direction and in the alternating procedure reverses itself and goes 50 times in the opposite direction, therefore, it alternates in direction 100 times a second.

The ampere rating of the electric motor refers to the amount of amperes it should use under normal operating conditions. The ampere is the unit of measurement for electric current. The ampere is the amount of electric current that flows past a certain part of the electric circuit during one second of time. An electric motor that is not drawing its rated ampere capacity, because of a light load, is not operating to its full maximum efficiency. While an electric motor that is drawing more than its rated ampere capacity, because of too heavy a load, is being overburdened. The life expectancy of an electric motor drawing more current than its rated capacity is greatly shortened. The high amount of current produces excess heat, which breaks down the enamel insulation on the wires, causing short circuits that burn out the motor.

1.4 Types of Electric Motors

Electric motors of many types are designed to meet specific operation requirements. The specifications may require that the motor operate on direct current or alternating current, with a light starting load or a heavy starting load, with a light constant speed work load or a heavy constant speed work load, with a low number of revolutions per minute or a high number of revolutions per minute. These basic requirements, as well as many others, can be a part of the operational design of a motor.

There are two types of motors that operate with direct current.

- (1) **Series motor.** In series type, direct current motors the armature coil and field coil are connected in series. Series motors because

of their high torque (turning power) and rapid acceleration are often used with heavy loads. Such motors are often used for automobile starters, cranes and hoists.

- (2) **Shunt motor** The shunt type direct current motor has the armature coil and field coil connected in parallel. Shunt type motors operate at a steady speed when connected to a light or heavy load. Shunt motors are often used to drive heavy duty machinery such as drill presses, lathes, and printing presses.

A small motor designed to operate on either direct current or alternating current is the universal motor.

- (1) **Universal motor.** The universal motor has the armature and field coil connected in series. The direction of the motors rotation can be changed by reversing the brush connections. The universal motor has a high torque and can be designed to operate with a wide range of speeds. The speed of the universal motor can also be controlled by connecting a variable resistor in series with one of the power lines. Universal motors, usually manufactured in small sizes, range from 1/100 to 3/4 horsepower. Universal motors are used in household appliances such as the fan, sewing machine, vacuum cleaner, and electric mixer.

The two most commonly used types of electric motors that operate on alternating current are the induction motor and the synchronous motor

- (1) **Induction motor.** The induction motor consists of two parts called the stator and rotor. The stator, which serves a similar purpose as the field coil in the direct current motor, is a set of coils wound in the frame of the motor. The magnetic field is caused to rotate electrically through the set of coils by the applied alternating current. The rotor is made of laminated steel inset with copper bars. There is no electrical connection between the stator set of field coils and the rotor. Instead, the magnetic field of the stator induces a current in the rotor. The

rotor then, by induced current, also becomes an electromagnet. As the magnetic field rotates electrically around the set of stator coils it induces magnetic fields in the numerous segments of the rotor. The induced attraction and repulsion between the stator and the rotor actually pushes the motor around and makes it run.

Induction motors require a start to get the motor running. Two stator windings, one called the running winding and the other called the starting winding are used. The starter winding, after the motor reaches running speed, is cut out automatically. The running winding then keeps the motor operating at normal speed. Induction motors are used on refrigerators, record players, ceiling fans, and many types of industrial machines.

- (2) **Synchronous motor.** The synchronous motor is an induction type motor that operates at a speed determined by the frequency of the alternating current supplied to it. When the alternating current supply frequency to the stator is 50 cycle and the rotor becomes magnetized steadily at 50 cycles, the motor attains synchronous speed. This means that the motor running at 50 cycles for 60 seconds attains a synchronous speed of 3,000 revolutions per minute. The motor then is keeping in step with the cycles of current. The synchronous motor has the advantage of operating at a constant speed as long as the frequency of the alternating current remains constant. The most common use of the synchronous motor is in the electric clock.

2. PRINCIPLES OF ELECTRO-MAGNETISM

2.1 Permanent Magnets

Magnets are usually classed under two types called *permanent magnets* and *temporary magnets*. Permanent magnets keep their strength for a long time. They are made from known magnetic materials such as iron, steel, nickel, and cobalt.

Temporary magnets keep their strength for only a short time. They are made from known non-magnetic materials such as copper, aluminium, gold, silver, and lead.

2.2 Magnet Wire

The *electromagnets* used in an electric motor are classed as temporary magnets. They are made from copper wire which is a non-magnetic material. Copper wire, because it is a good conductor of electricity is called *magnet wire*. Magnet wire used in electric motors is usually insulated with a baked enamel coating. The baked enamel coating provides the best insulation and withstands high motor operation temperatures. Magnet wire, for protection against damage prior to use, should be purchased on a wood, metal, or plastic spool. The common sizes manufactured range from No. 14 (large) to No. 36 (small).

2.3 Magnetic Field

Electric current passing through a single wire, as shown in Figure 2.3.A, forms a *magnetic field* around the wire. The magnetic field is round in shape and its strength depends upon the amount of current passing through the wire. The larger the amount of current, the stronger the magnetic field. If the single wire is wound into a continuous series of loops, called a *coil*, less magnetic lines

of force will surround each individual turn and more will pass lengthwise through the length of the coil. The end at which these magnetic lines of force leave the electromagnetic coil becomes the north pole, and the opposite end where the magnetic lines of force re-enter the electromagnetic coil becomes the south pole. The larger the number of turns in the electromagnetic coil and the higher the current flowing through it, the stronger the *magnetic force* that is generated.

2.4 Soft Iron Core

A core of soft iron placed inside the electromagnetic coil will greatly increase the strength of the magnetic field. This is because the magnetic lines of force will pass more readily through a soft iron core than through air. As a result, in comparison to the open air coil, an enormous number of magnetic lines of force now pass lengthwise through the coil and a stronger magnetic force is generated.

2.5 Polarity Rule

The *polarity* of an electromagnet depends upon the direction of the current passing through its coils. The polarity of a coil energized by direct current remains the same because the current flow is in one direction. The polarity of

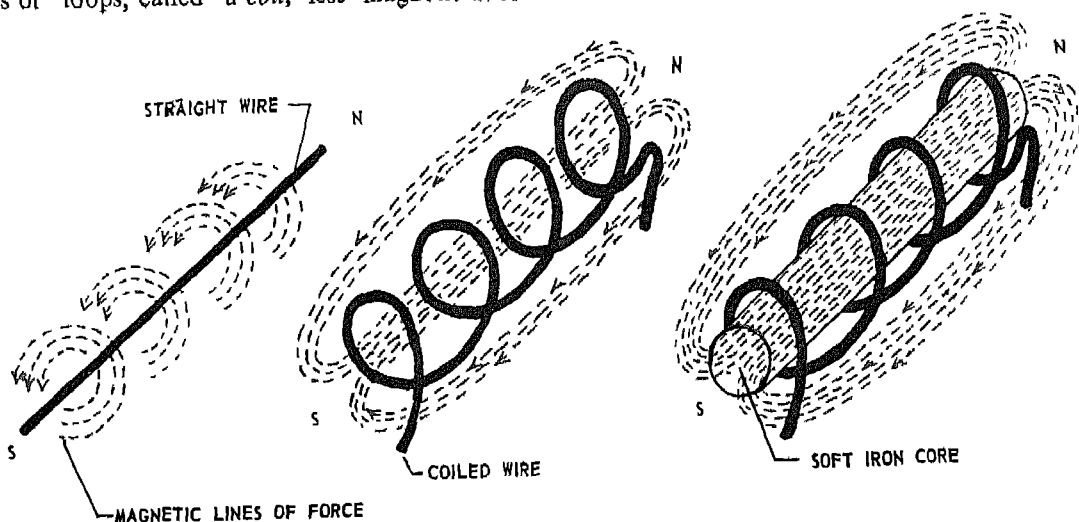


Fig. 2.3 A Electromagnet

a coil energized by alternating current constantly changes because the current alternates. The *left hand rule*, as shown in Figure 2.5 B, is used to

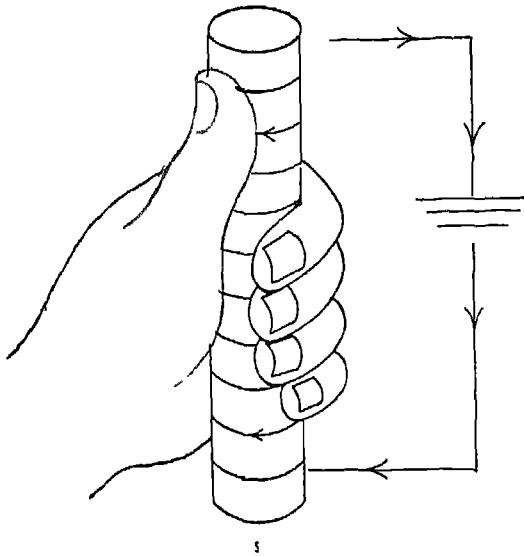


Fig. 2.5.B Left Hand Polarity Rule

determine the polarity of a coil when energized by current. Place the fingers of the left hand around the coil in the direction of the current flow and the thumb will point toward the north pole.

2.6 Electric Motor Operation

The principle of the electromagnet has certain advantages that should be noted in their application and operation of the electric motor.

- (1) Copper wire is classified as non-magnetic yet it is a good conductor of electricity. This permits the magnetic field to be rapidly built up and collapsed.
- (2) Soft iron, classified as a magnetic material, makes a weak magnet. However, it possesses the potential to build up a strong magnetic field and collapse it quickly.
- (3) The energy output of the electromagnet can be varied depending upon the number of turns of wire in the coil, the size of the core and the strength of the current flowing through the coil.
- (4) The energy output of the coil is controllable. Because, when a source of current is supplied, a strong magnetic force is rapidly built up around the coil, yet when the current is interrupted the magnetic field collapses and the coil ceases to be a magnet.

The application of the principle of the electromagnet to the design of an electric motor, utilizing a controlled rapid build up and collapse of a strong magnetic field, is the actual force that changes the electrical energy into mechanical energy.

3. ELECTRIC MOTOR EXPERIMENT

MATERIALS

3.1 Wood

The motor base is made of wood. Because of its strength and softness, wood provides the easiest method of mounting the metal motor parts with screws or nails. It is also a non-conductive material and, therefore, acts as an insulation between the metal motor parts.

3.2 Metal

The motor can be made from several different types of metal. Availability of the metal should be the determining factor. The motor parts can be fabricated from tin cans by cutting the cans and flattening the tin. Sheet metal, either black, tinned, or galvanized, in any gauge between 20 to 26 is suitable for fabricating the motor parts. Soft steel in strap form, such as $1/16" \times 1"$, or $1/8" \times 1"$ will make a very sturdy and efficient motor. Brass in sheet form, although not absolutely necessary, is most suitable for the bearing brackets, brushes, and commutator segments. Brass will reduce the amount of friction between the revolving armature and the bearing bracket. Brass brushes and commutator segments will also reduce friction, and greatly increase the electrical contact between the revolving commutator and stationary brushes because brass is a good conductor of electricity.

3.3 Metal Rod

A light, thin, long round metal rod is needed for the armature shaft. A bicycle spoke will work very satisfactorily. Any other round piece of metal, such as a knitting needle, knitting pin, nail, drill rod, or welding rod, may be substituted.

3.4 Reel

A small paper reel, from a reel of thread, is very suitable for constructing the commutator. It has the advantage of being round, with a hole through the centre, and, therefore, it will revolve quite true. Other materials such as a cork or a round piece of wood may be used, except the hole will have to be bored quite accurately and the outside surface must turn true if the commutator is to operate efficiently.

3.5 Wire

The wire used for the field coil and the armature must be insulated. Enamel coated copper wire works very well and is the least expensive. Cotton covered copper wire is satisfactory but costs a little more. No. 24

copper wire is a good size to use for this type of motor, which is designed to operate on 6 to 12 volts DC. A wire of any number between 22 and 26, will, however, work. To prevent kinks and bends while using, slip the spool of wire on a rod and allow it to turn freely.

3.6 Hardware Fasteners

Small brass screws, such as Round Head $1/2"$ —No. 4, are very suitable for mounting the metal motor parts on the wood base. Screws have the advantage of allowing the metal parts to be shifted slightly for proper alignment and then be retightened. Nails will also work, but it is more difficult to align the motor parts, and the vibration from the running motor may cause the parts to shift out of alignment.

ELECTRIC MOTOR EXPERIMENT PROCEDURE

3.7 Base

Make the wood base to the approximate size of $1/2" \times 5" \times 8"$. A larger sized base, however, may make assembling of the motor much easier and provide more stability during the motor operation.

3.8 Armature Shaft

Cut the bicycle spoke to be used for the armature shaft, as shown in Figure 3.8.A, to 4" in length. Make a cone-shaped point at both ends of the armature shaft. The points serve as thrust bearings to reduce the end play in the armature shaft.

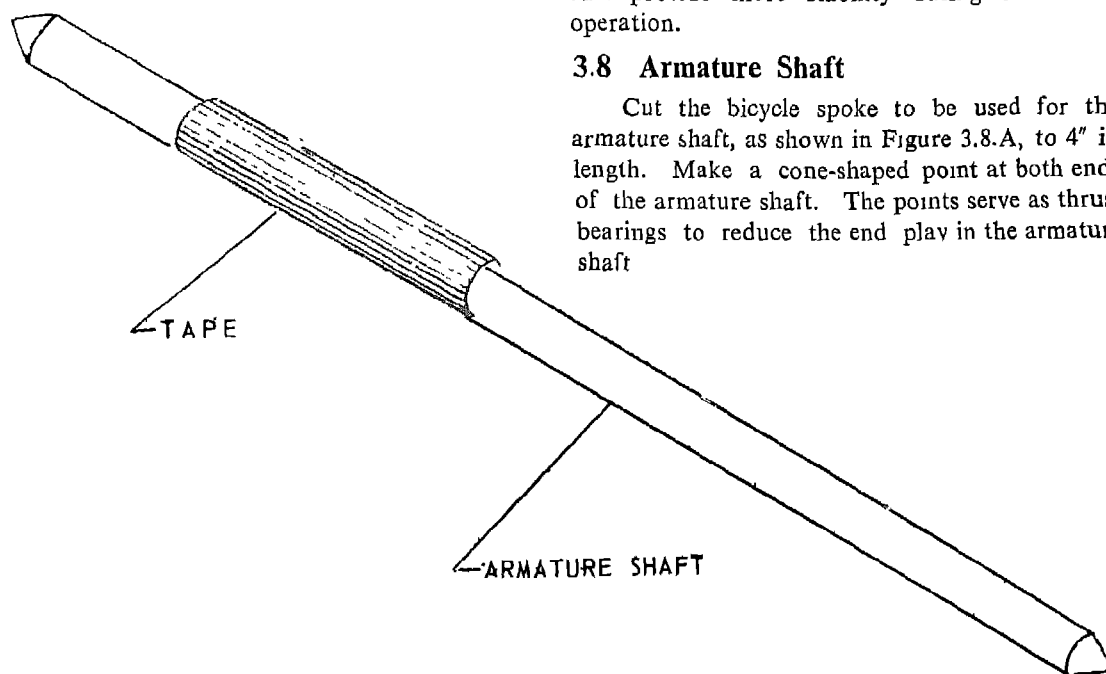


Fig. 3.8.A Armature Shaft

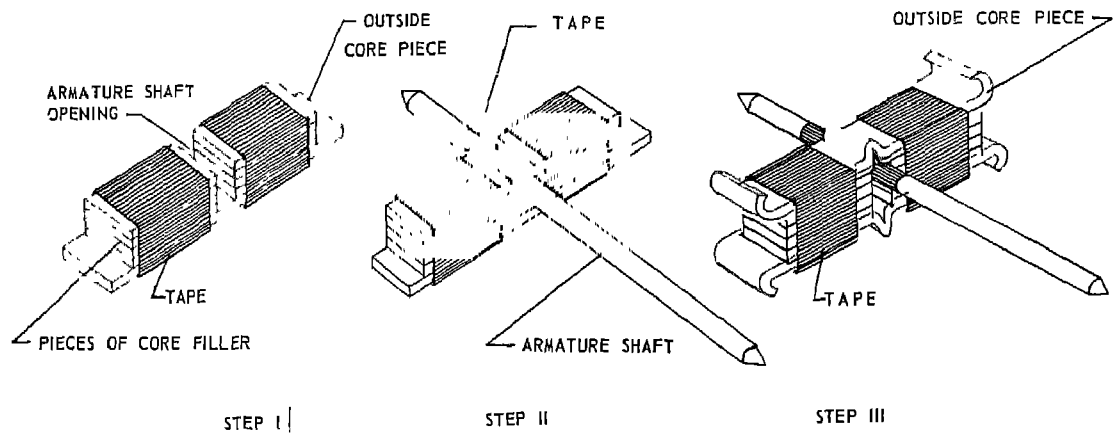


Fig. 3.9 A Armature Core Assembly

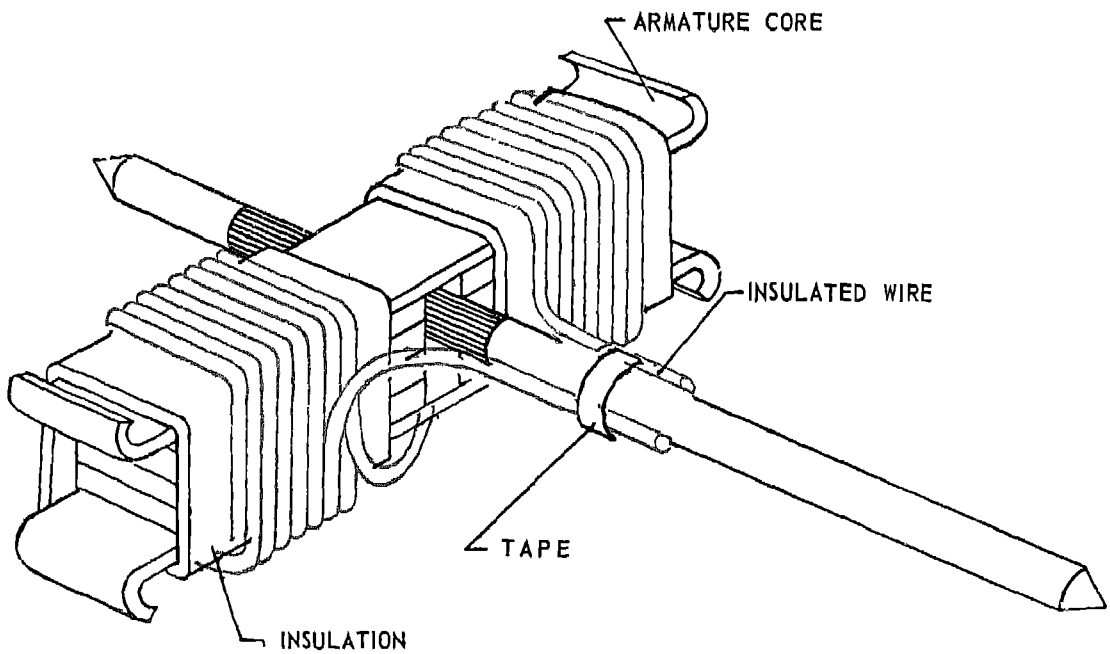


Fig. 3.9,B Armature Winding

Wrap the armature shaft $1/2''$ from one end with a $1''$ wide piece of tape. The tape will provide enough friction to hold the armature core in proper alignment with the armature shaft.

3.9 Armature

Cut two pieces of metal $1''$ wide and $3''$ long for the outside of the armature core.

Cut enough pieces of metal $1'' \times 1''$, for filler laminations between the outside core pieces, to match the thickness of the armature shaft. The laminated pieces will increase the magnetic field of the armature coil, as well as serve for filler laminations in the armature core.

Fasten, as shown in Figure 3.9.A, the $1'' \times 1''$ metal filler pieces to one of the $1'' \times 3''$ outside core pieces. Leave space in the centre for the armature shaft. The core pieces may be fastened into position by either tape, solder, or paper and glue. Force the wrapped portion of the armature shaft, snugly into the space between the filler pieces. Fasten the other outside core piece into position.

The armature core, as shown in Figure 3.9.B, must be wrapped with insulation to insure that the armature winding does not short out against the armature core. Any insulation such as paper, tape, or cloth may be used. The insulation should be securely fastened with tape, string, or glue.

Approximately 75 ft. of No. 24, enamel-coated copper wire, as shown in Figure 3.9.B, is needed to wind the armature coil. However, any number between 22 and 26 will work satisfactorily. Find the centre of the wire and mark the location with a piece of tape.

Tape one end of the wire, approximately $1''$, to the armature shaft. Wind the wire, starting at the armature shaft, around the paper insulation. Wrap the wire neatly, keeping each turn snug against the other. When the outer edge of the paper insulation is reached, wrap the second layer over the first, back toward the armature shaft. Continue wrapping until one

half of the wire is wrapped on one side of the armature core. Cross over, still winding in the same direction, and wrap the first layer of wire neatly around the other paper insulation. When the outer edge of the paper insulation is reached, wrap the second layer, over the first, back towards the armature shaft. Continue wrapping until approximately $1''$ of wire to connect to the commutator is left. To prevent the coils from unwinding secure them to the armature shaft with a small piece of tape.

3.10 Commutator

The commutator is to be positioned on the armature shaft, as shown in Figure 3.10.A, approximately $1/4''$ from the armature. Bend the ends of the armature winding wire back out of the way. Wrap the area with enough tape or paper and glue, to match the inside diameter and length of the paper reel. Fix the paper reel firmly on to the taped armature shaft. The armature shaft should center itself in the hole of the reel, provided the tape or paper has been applied evenly around the armature shaft.

Cut two commutator segments according to the size of the paper reel that has been obtained. If a paper reel $1/2''$ in diameter by $1-1/2''$ long has been obtained, a commutator segment size of $5/8'' \times 1''$ will work very well. Form each segment smoothly to fit around the reel. A sufficient gap should be allowed between each segment to prevent the brush from touching the two segments at one time. If thick commutator segments are used, a level filed on each end helps to eliminate the possibility of the brushes touching two segments at a time. It also makes the brushes ride on and off the commutator segments more smoothly. Remove the enamelled insulation from the ends of the commutator winding wires. Cut the commutator wires so that they extend approximately $1/4''$ under the edge of the commutator segments. Align two commutator segments on the reel so that the gap between the two segments, if the armature is held flat, comes at the sides of the armature shaft. This is very important if the motor is to run at its peak magnetic efficiency

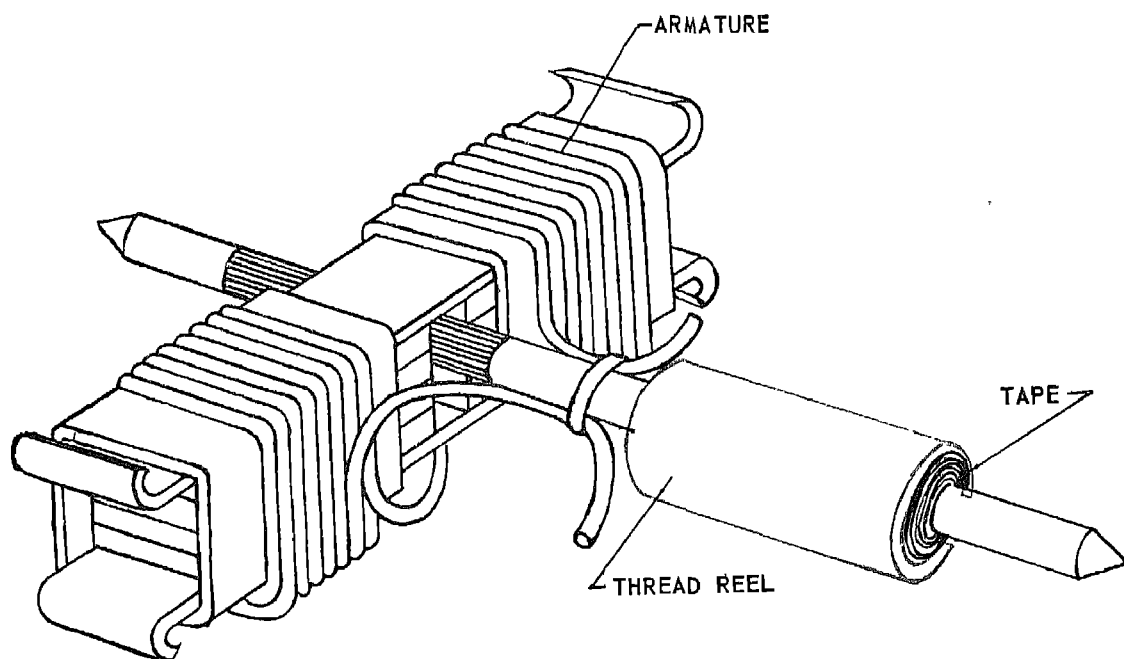


Fig. 3 10,A Commutator Assembly
STEP I

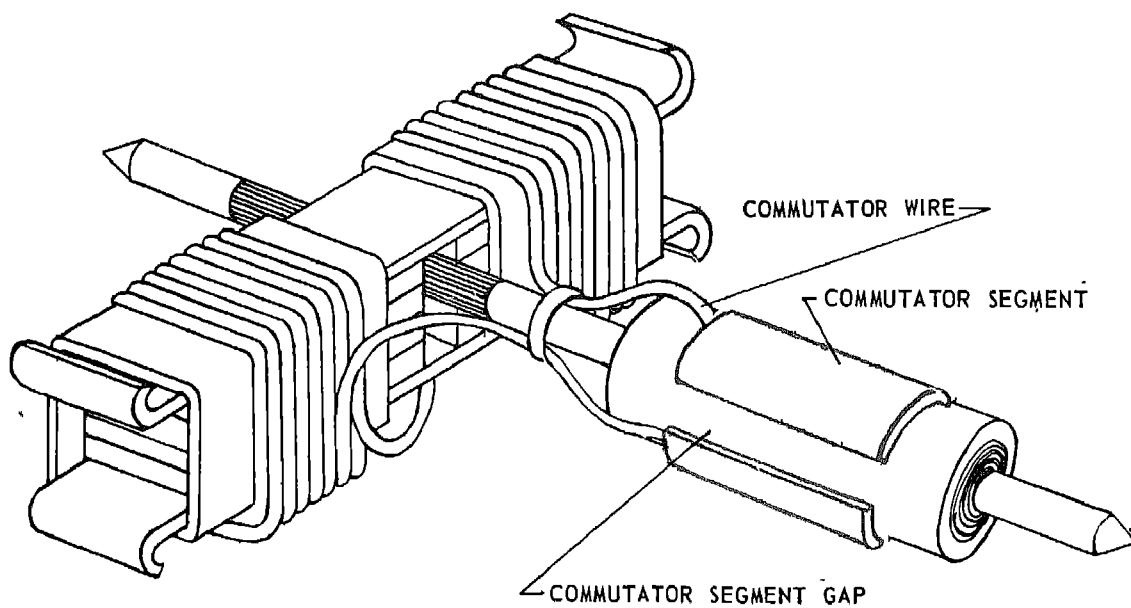


Fig. 3.10.A Commutator Assembly
STEP II

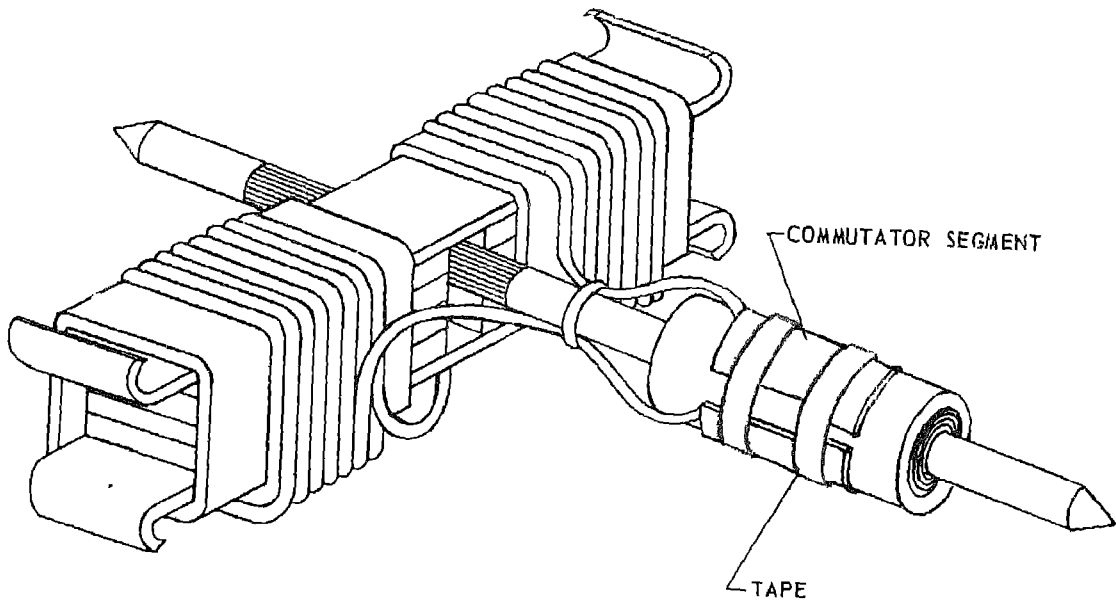


Fig. 3 10 A Commutator Assembly
STEP III

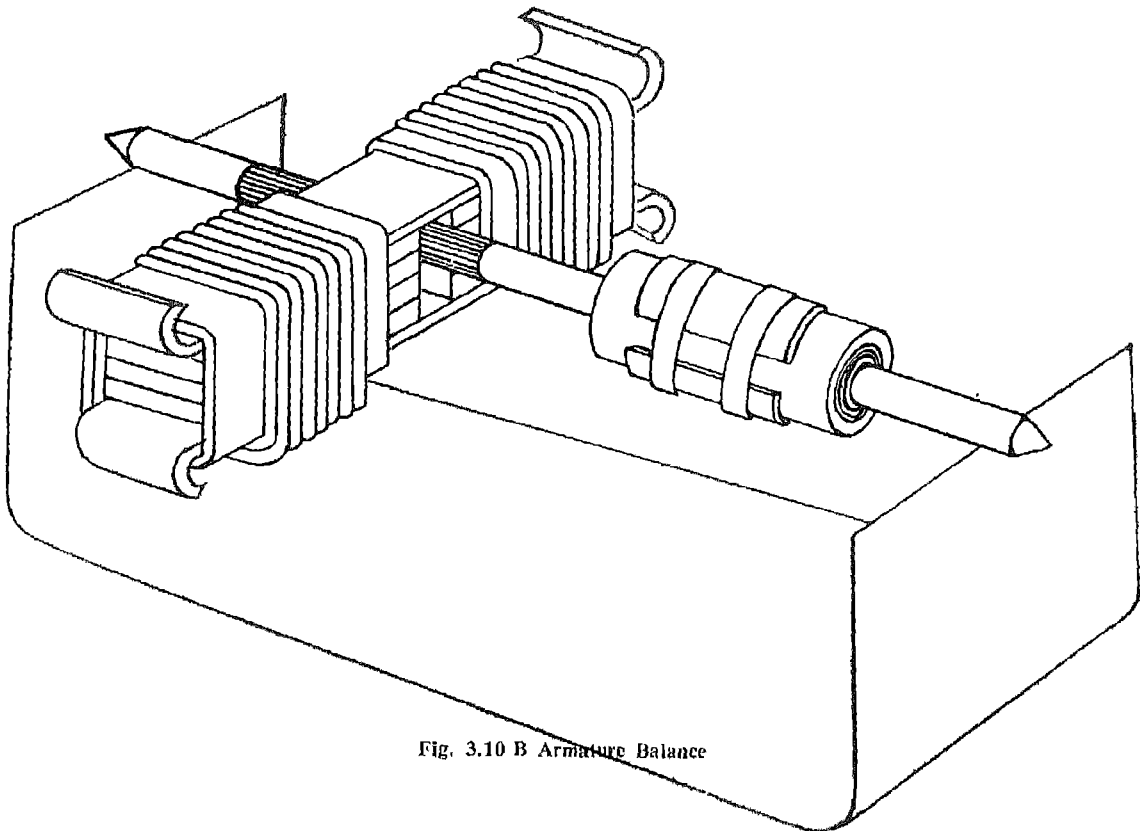


Fig. 3.10 B Armature Balance

and maximum speed. Tape the commutator segments, as shown in Figure 3.10 A, Step III, in their proper position.

Bend the ends of the armature core to conform to a $2\frac{1}{4}$ " diameter circle. The armature, to run true at high speed and be vibration free, should be balanced. To check the armature for balance, as shown in Figure 3.10 B, support it horizontally on two thin metal edges. Balance the armature accurately by trimming the metal from the bent ends of the armature core.

3.11 Bearing Brackets

Bearings are usually classified under two types called radial bearings and thrust bearings. *Radial bearings* receive the radial pressures from a revolving shaft. *Thrust bearings* receive the end thrust or pressures from a revolving shaft. The bearing bracket for this motor is designed to provide both radial bearing and thrust bearing support for the shaft.

Cut the bearing bracket metal, as shown in Figure 3.11 A, approximately 1" wide and $1\frac{1}{4}$ " long. Drill a hole the size of the armature shaft $1\frac{3}{4}$ " from one end. Drill two holes at opposite ends for mounting the bearing bracket. For purpose of armature shaft alignment, all holes should be drilled on centre. Form the two bearing brackets so that they match each other as closely as possible. This will improve alignment and reduce friction.

Draw a centre line the length of the wood base. Locate the armature shaft and bearing brackets on

the centre line. Drill anchor holes and mount one bearing bracket with screws. Fix the other bearing bracket so as to allow free rotation of the armature shaft and permit a slight amount of end play. Drill anchor holes and mount the second bearing bracket with screws. When the armature shaft is properly aligned in the bearing brackets the armature shaft should revolve freely.

To reduce friction and wear on the armature shaft and bearing bracket place a drop of oil in each bearing hole and at the end where the shaft touches the bearing bracket. A film of oil placed in a bearing will support the shaft clear of the bearing surface. The reduction of friction and wear will improve the free running operation of the motor.

3.12 Field Coil

Cut several pieces of metal 1" wide and 10" long for the field coil frame. If a tin can is used cut at least five pieces to be laminated together. The laminated pieces will increase the magnetic field of the coil and add stability to the frame.

Form the inside laminated piece first and place it over the armature to ensure that there is ample clearance between the field coil frame and the revolving armature. Remember, the field coil winding will protrude at least $\frac{1}{4}$ " below the field coil frame. Therefore, allow ample clearance for winding the field core wire. The inside measurement of the field coil frame, as shown in Figure 3.12.A, is $2\frac{1}{2}$ " wide and $2\frac{3}{4}$ " high to allow the $2\frac{1}{4}$ "

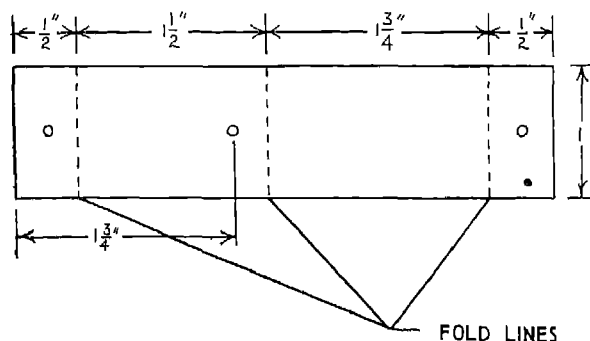
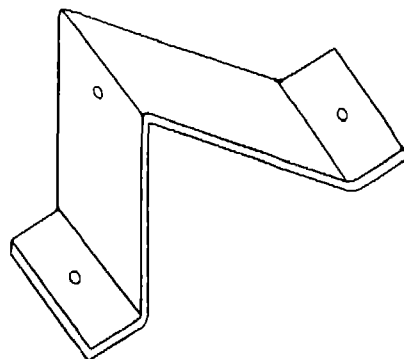


Fig. 3.11.A Bearing Bracket



armature to revolve freely with a minimum of clearance. Form the rest of the laminated frame to fit over the first formed piece. Drill mounting holes in the feet and bolt the pieces together. The bolts, although not absolutely necessary, serve as a convenient method of holding the laminations together while insulating the frame and winding the field coil.

The laminated frame must be wrapped with insulation to ensure that the field coil winding

Tape one end of the field coil wire approximately 5", to one side of the field coil frame. Later on, after being untaped, the wire will serve as an electrical connection. Wrap the field coil wire neatly, keeping each turn snug against the other, across the insulated part of the frame. When the far side is reached, wrap the second layer, over the first, back towards the starting end side. Continue wrapping back and forth across the insulated frame until all of the wire is wrapped into the frame. Fasten the last

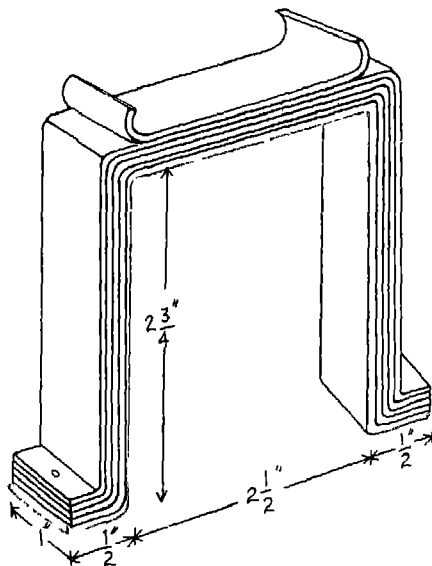
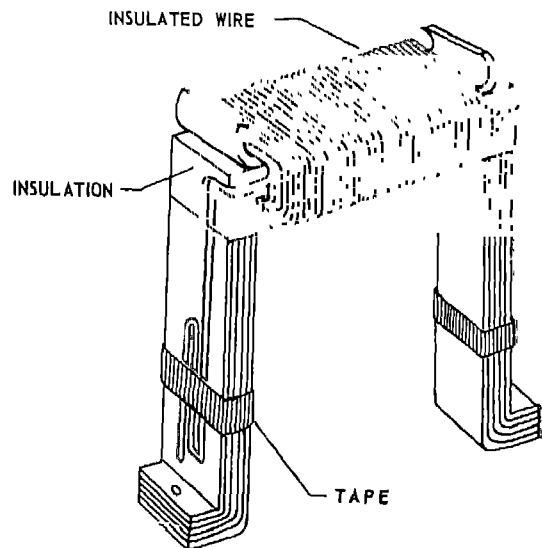


Fig. 3.12.A Field Coil Assembly



does not short out against the field coil frame. Any insulation such as paper, tape, or cloth may be used. The insulation should be securely fastened with string or glue.

Approximately 150 ft. of No. 24 enamel coated copper wire, as shown in Figure 3.12.A, is needed to wind the field coil. However, any number between 22 and 26 will work satisfactorily.

5" of wire, with tape, on the far side of the laminated frame

Remove the nuts and bolts from the feet of the field coil frame. Place the field coil directly over the armature coil. Centre the armature accurately in the opening of the field coil frame. Mark on the wood base, the centre of the mounting holes in the feet of the field coil frame. Drill anchor holes and mount the field coil to the wood base with screws.

3.13 Brushes

Cut two pieces of metal $\frac{3}{4}$ " wide and $2\frac{1}{4}$ " long for the brushes. Bore two holes, as shown in Figure 3.13 A, for screws. Trim the other end, as the design shows, to approximately $\frac{1}{4}$ " in width. The narrow end permits the brush to ride on the commutator with less friction, and yet, provides ample surface for good electrical contact through a moving part. Bend the brush, with an intermediate angle in between, to permit the electrical contact end to be at right angles to the foot.

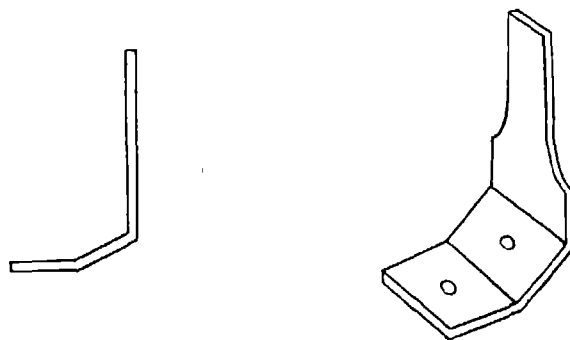
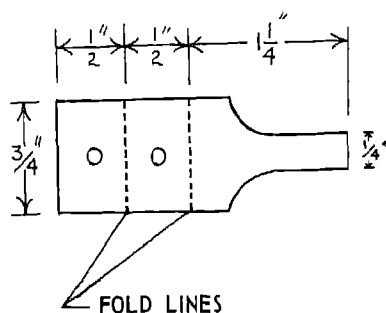


Fig. 3.13.A Brushes

Place each brush in a centred position at the commutator, with a slight amount of clearance between the brush and the commutator. Mark on the wood base, the centre of the foot-mounting holes. Drill anchor holes and mount the brushes in their tentative positions. Align the brush accurately to ensure that the contact surface parallels the commutator surface. Drill anchor holes, through the hole in the angular part of the brush, into the wood base. Place a screw through the hole and tighten it enough to allow the brush to touch the commutator.

3.14 Series or Parallel Wound Motor

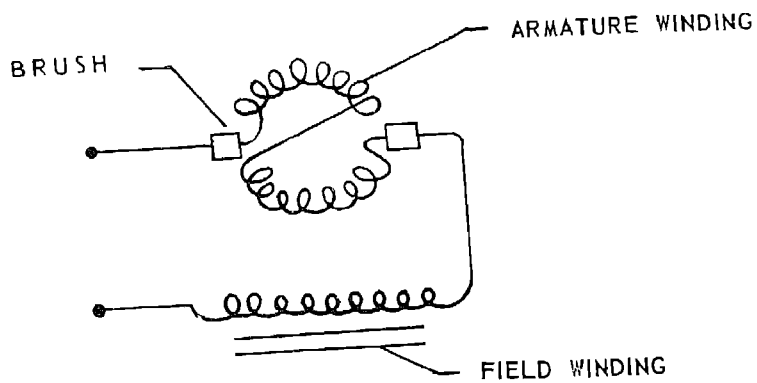
The electric motor has been specifically designed to operate efficiently on a 6 volt DC or

12 volt DC car battery. The motor may be wired in SERIES or in PARALLEL as shown schematically and pictorially in Figure 3.14.A, or Figure 3.14.B. It may be advisable to avoid prolonged periods of 12 volt operation in the parallel wound motor, because of over-heating. If the operator can hold his hand on the field coil at any time the motor is running, the motor is operating within the breakdown limitations of the wire insulation.

Strip all the enamelled insulation from the

ends of each wire connection. Loop the wire completely around the body of the screw and then tighten the screw. A wire, for a good electrical connection, should always be looped around a screw or bolt in the direction of tightening.

Connect the motor leads, as shown in Figure 3.15.A, to a 6 volt DC or 12 volt DC source of power. Adjust the brush tension with a screw driver, as soon as the motor starts, until maximum revolutions per minute (R P M.) is achieved. Several brush adjustments, alternately on each brush, may be necessary to obtain equal tension and electrical contact. Also, the spring type action of this brush enables the brush to remain in perfect contact with the commutator even though the commutator may have a slightly irregular shape.



SCHEMATIC

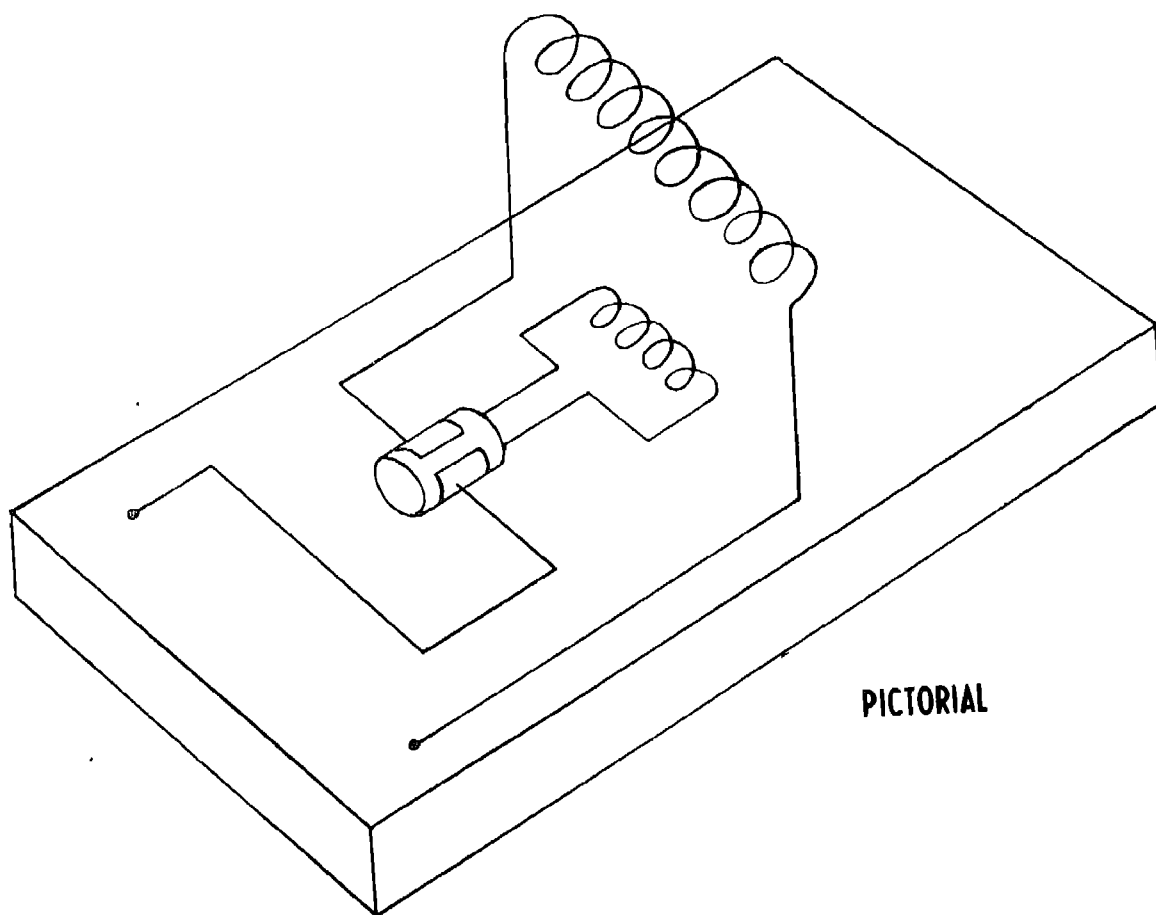
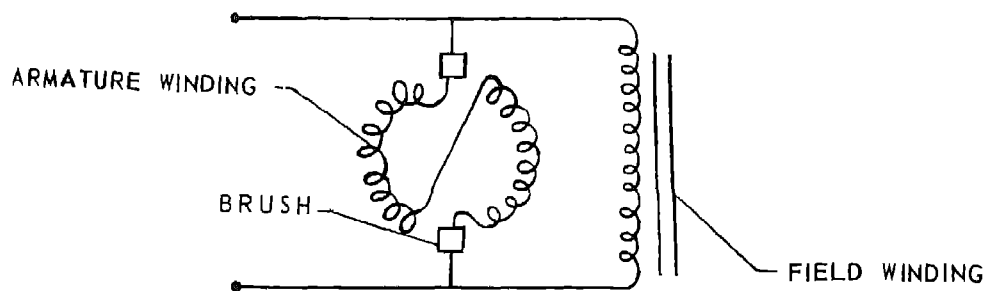


Fig. 3.14.A Series Wound Motor



SCHEMATIC

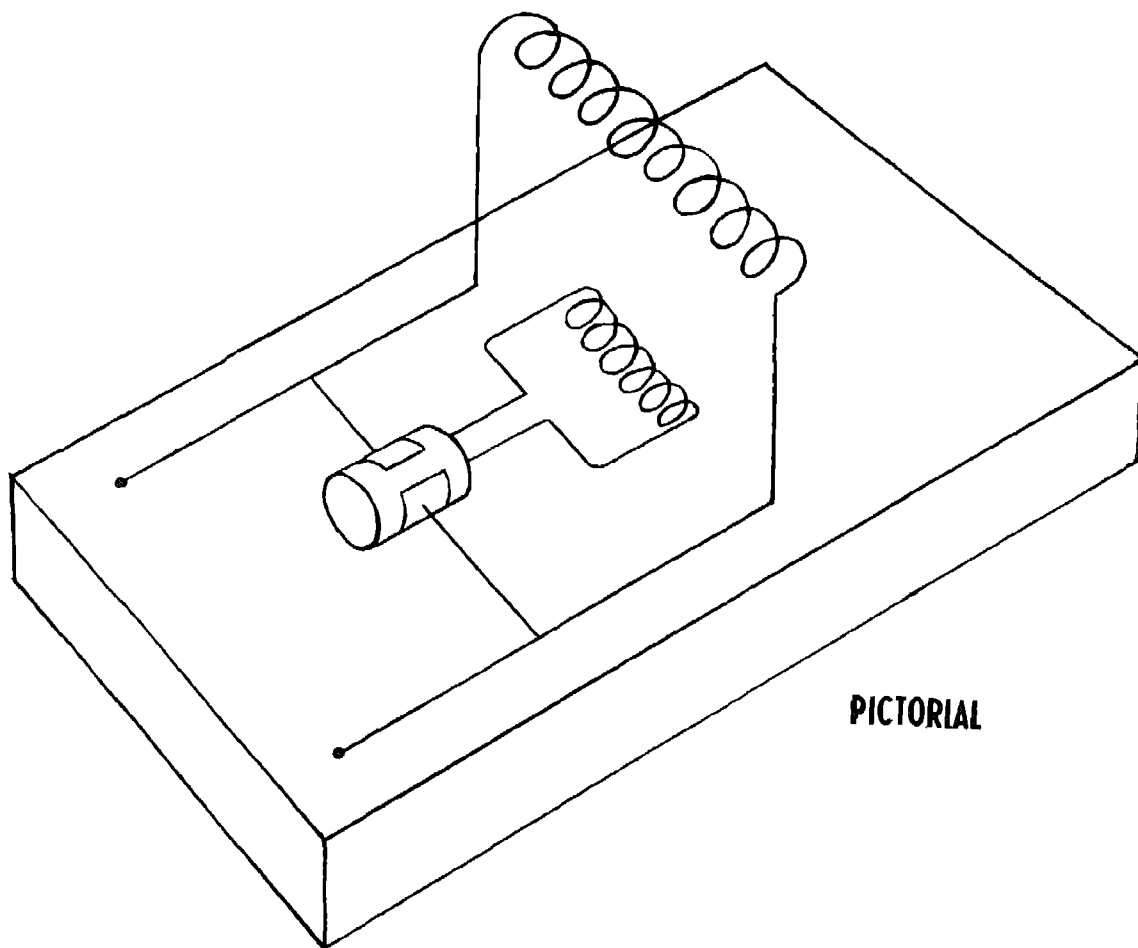


Fig. 3.14.B Parallel Wound Motor

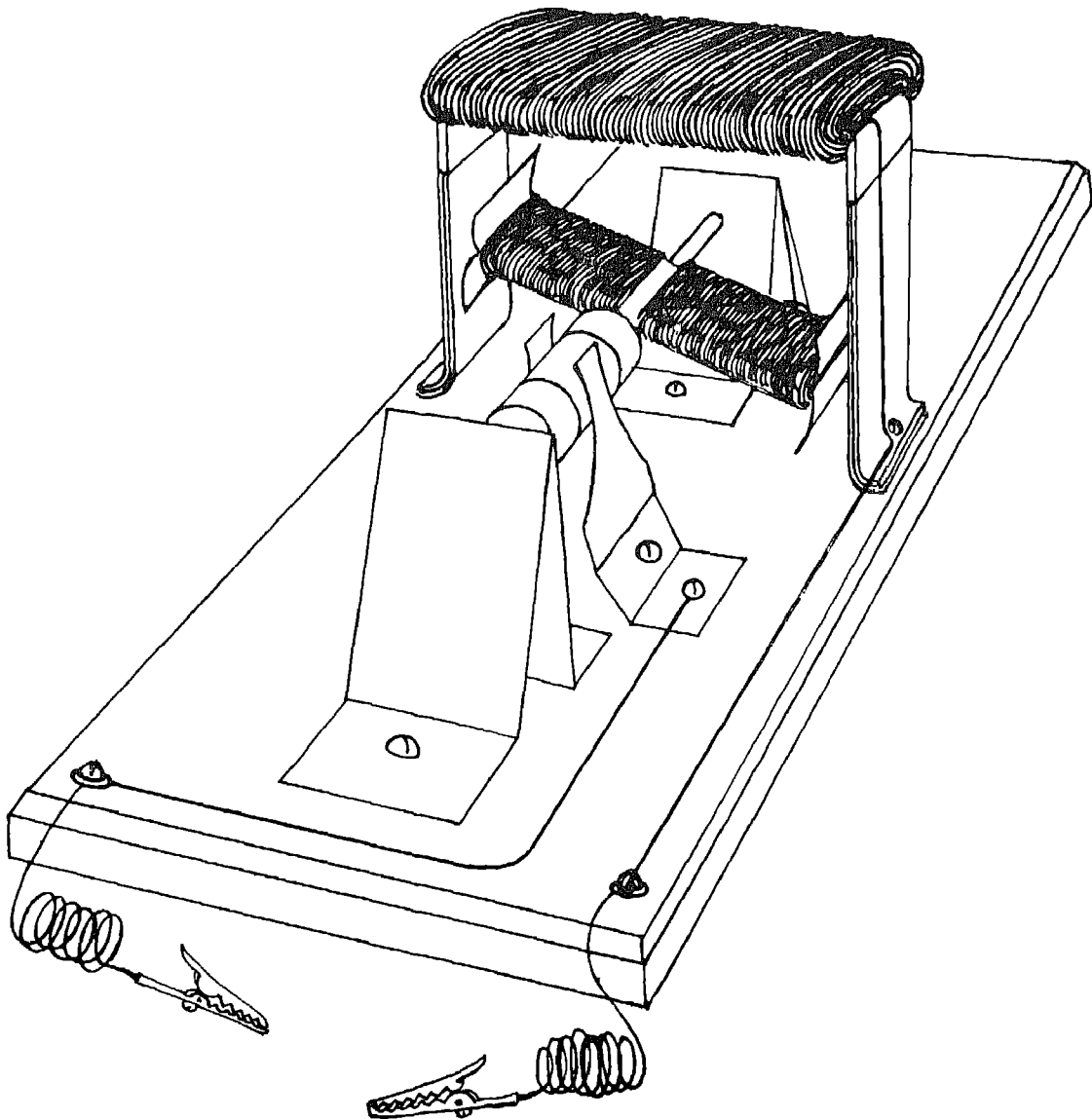


Fig. 3.15.A Pictorial Diagram of Electric Motor

STUDY QUESTIONS

The Electric Motor Unit contained many important ideas and practices of electricity that you should understand. The following questions have been listed as types that your instructor will use for internal grading. Therefore, review this unit well until you are able to answer all the questions easily and correctly. If you are unable to understand the questions or find the answers, please see your instructor for help

ESSAY QUESTIONS

Essay questions should be designed to provide the student with the opportunity to express, in writing, technical information on a limited subject. Each student can be assigned a different topic or the same topic. The advantage of different topics is that it will provide the teacher with a broader reaction to all of the materials studied.

1. Describe how electrical energy is transformed into mechanical energy.
2. Describe the significance of the name plate and the specific details it gives about the operation of the motor.
3. Describe the principle of electromagnetism.
4. Describe the steps involved in making the commutator assembly for a small electric motor.
5. Select two mechanical parts of the electric motor, (such as the bearings, brushes, or magnet wire), and describe in detail, the technical information an electrician should know about each mechanical part.

TRUE AND FALSE QUESTIONS

The following statements are either TRUE or FALSE. Fill in the blank at the left of the number with a + sign for the true questions and a O sign for false questions.

- ___ 1. An electric motor may be defined as a machine that transforms electrical energy into mechanical energy.
- 2 The strength of an electromagnet can be controlled.
- ___ 3. One horsepower is equal to 764 watts of electric power.
4. The synchronous motor is a variable speed motor.
5. The shunt type, direct current motor has the armature coil and field coil connected in parallel.
- ___ 6 Permanent magnets keep their strength for only a short period of time.
7. The larger the number of turns in the electromagnetic coil and the higher the current flowing through it, the stronger the magnetic force that is generated.
- ___ 8. The polarity of a coil energized by direct current changes because the current alternates.
9. The right hand polarity rule is used to determine the polarity of a coil when energized by current.
10. A film of oil placed in a bearing will support the shaft clear of the bearing surface

COMPLETION QUESTIONS

The following statements will all be true with the addition of one or more words. Fill in the blank at the left of the number with the correct word or words that completes the sentence.

- ___ 1 The principal of and.....of magnetic poles causes the change of electrical energy into mechanical energy.
2. A horsepower is the amount of effort required to lift a weight of pounds, a distance of foot in second of time.

3. The number of times a motor shaft revolves in one minute is referred to as ...
4. Motors are usually designed to operate on either ... current or ... current.
5. A ... is the number of times that ... current reverses in direction in one second.
6. An electric motor that is not drawing its rated ampere capacity, because of a ..., is not operating to its full maximum efficiency.
7. Too high an amount of current in a motor produces excess heat, which breaks down the ... insulation on the ...
8. magnets keep their strength for only a short time.
9. Electric current passing through a wire forms a ... around the wire.
10. A... placed inside the electromagnetic coil will greatly increase the strength of the electromagnet.
11. The armature, to run true at high speed and be vibration free, should be
3. A synchronous motor attains a speed of.... .. revolutions per minute.
 - (1) 50 (3) 220
 - (2) 60 (4) 3,000
4. Temporary magnets are made from known non-magnetic materials such as.....
 - (1) iron (3) nickel
 - (2) copper (4) cobalt
5. The friction between the moving parts of the motor can be reduced to a minimum if they are made of.
 - (1) steel (3) brass
 - (2) copper (4) tin

PROBLEM QUESTIONS

Problem questions should be designed to provide the student with the opportunity to express, in writing, technical information on a limited problem. Each student can be assigned a different problem or the same problem. The advantage of different problems is that it will provide the teacher with a broader reaction to all of the materials studied. Students should be required to show the correct procedure for solving the problem and include all calculations.

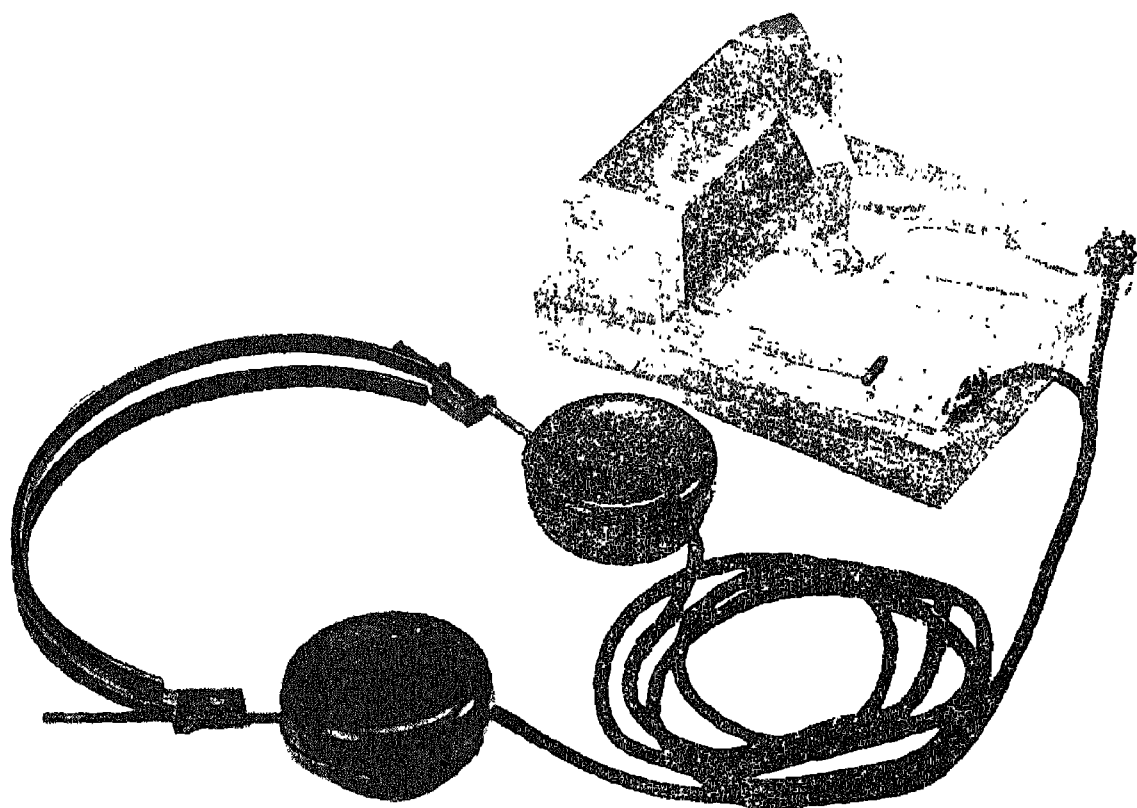
MULTIPLE CHOICE QUESTIONS

The following statements will all be true with the addition of one or more words. Place the number of the word, or group of words, that correctly completes the sentence in the blank to the left of the question number.

1. Today, in technically advanced countries, electric motors furnish.... ..per cent of the mechanical power.
 - (1) 70 (3) 90
 - (2) 80 (4) 100
2. The. motor consists of two parts called the stator and the rotor.
 - (1) series (3) universal
 - (2) shunt (4) induction
1. Parallel Wound Motor. Draw a pictorial diagram for a small parallel wound electric motor and make a matching schematic diagram.
2. Series Wound Motor. Draw a pictorial diagram for a small series wound electric motor and make a matching schematic diagram.
3. Mechanical Trouble Shooting. List five mechanical defects that may effect the efficient operation of a motor. Describe how to make the necessary repairs or adjustments.
4. Electrical Trouble Shooting. List five electrical defects that may effect the efficient operation of a motor. Describe how to correct the electrical difficulties.

REFERENCES

- Buban, Peter and Schmitt, Marshall L. *Understanding Electricity and Electronics*. New York: McGraw-Hill Book Company, Inc., 1963.
- Gerrish, Howard H. *Electricity*: Chicago : Goodheart-Wilcox Company, Inc., 1961.
- Steinberg, William B., and Ford, Walter B., *Electricity and Electronics*. Chicago: American Technical Society, 1961.
- Turner, Rufus P. *Basic Electricity*. New York: Holt, Rinehart and Winston, 1963



Working Model of the Crystal Radio

Unit 4

CRYSTAL RADIO

1. TRANSFORMING ELECTRICAL ENERGY INTO RADIO-COMMUNICATION

RADIO RECEIVERS are becoming a popular part of everyday life throughout the world, especially the new small portable styles that can be used in the home or carried on the streets. Radio communication is important from the standpoint of news and music. It is even more important in a highly technical world because of its contribution of direct contact by voice whether between land, sea, air stations.

Communication involves both transmission and reception. The transmitter can be of any size from a small portable style that will broadcast one mile, to a large powerful transmitter that will broadcast thousands of miles. The receiver can be anything from a simple crystal set that will pick up broadcasts from close range, to a powerful receiver that will pick up broadcasts from thousands of miles. The basic principle of transmission and reception between any of these units is the same. However, the units vary greatly in their complexity of construction and cost.

1.1 Principle of Radio Communication

The principle of radio communication, illustrated pictorially in Figure 1.1.A, shows the entire concept of radio communication from the time you speak until the time you are heard, perhaps many miles away.

When a person speaks, his voice projects sound waves that strike the microphone. The microphone produces a weak electrical impulse that changes the sound waves into radio waves. The transmitter combines the radio waves with carrier waves and increases their power. The combined radio waves and carrier waves are sent out from the transmitter aerial. The carrier waves travel through space at the speed of light, 186,000 miles per second. When they strike a radio aerial they are carried to the radio receiver. The radio receiver separates the radio waves from the carrier waves, and converts the radio waves into sound waves. The sound waves enter the ear and the original voice is heard.

1.2 Sound Waves

When you play a violin, as shown in Figure 1.2.A, a sound is heard because the string is vibrating. The faster the string vibrates the higher the note. The slower the string vibrates the lower the note. Have you ever thought that as you speak your vocal cords are vibrating, just like the string on the violin? If you take a deep breath and say, 'AAH... ..', the stream of air expelled by your lungs vibrates your vocal cords. The vibrations which are forth and back movements, cause the air to be compressed and decompressed. The decompressed air, which is a low pressure area, is called *rarefaction*. This compression and rarefaction of the air, as shown in Figure 1.2.B, forms the sound waves.

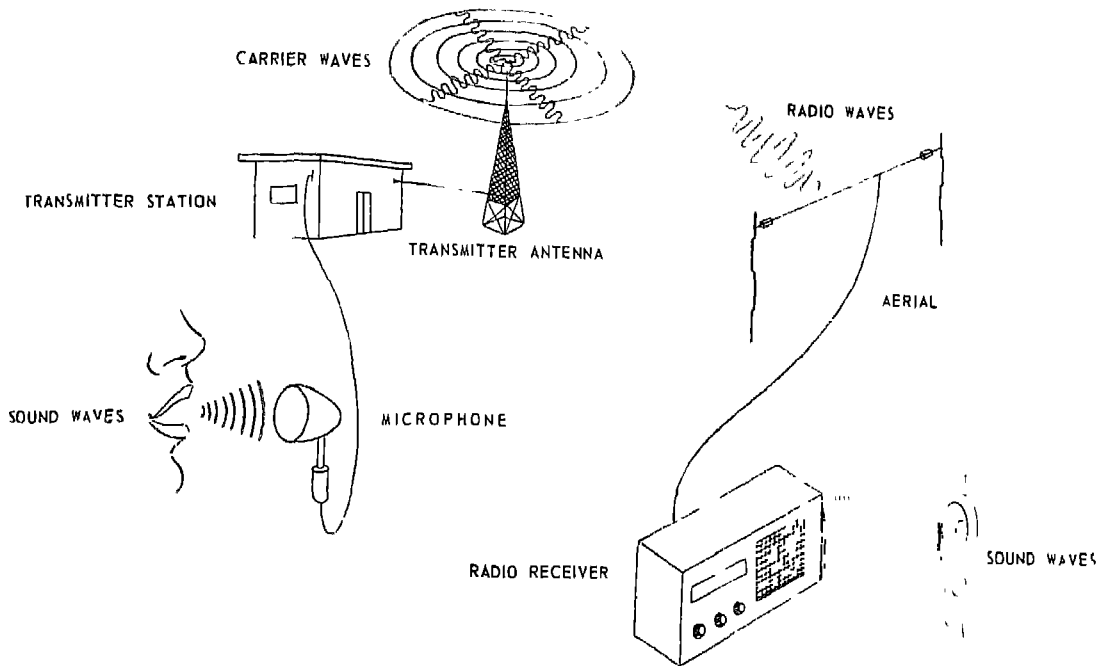


Fig 1.1.A Radio Communication

The voice produces sound waves that vibrate within the *audio frequency* of the ear. *Audio* means, 'to hear'. *Frequency* means, 'the number of cycles completed in a given period of time'. The human ear can hear sound waves that vibrate at audio frequencies of 16 to 20,000 cycles per second. Sound waves travel through the air at a speed of about 1,100 feet per second

1.3 Microphone

The voice creates sound waves that cause rapid variations in air pressure. As these air pressure variations reach the microphone they strike a thin metal diaphragm. The metal diaphragm being very sensitive, feels these slight air pressure variations. The variations in air pressure cause the metal diaphragm to vibrate in step with the sound waves. The metal diaphragm, as shown in Figure 1.3.A., vibrates against a carbon powder in a chamber behind the diaphragm. When there is no air pressure on the metal diaphragm, the carbon powder is loose and the electrical resistance of the

carbon powder is high. This restricts the flow of current and makes it weak. When the carbon powder is compressed, due to an increase of air pressure pushing the diaphragm, the electrical resistance of the carbon powder is decreased. This permits a stronger current flow. Thus, the compression and decompression of the carbon powder varies the current flow and represents electrically the same sound waves created by the voice. The electrical current flow is a *pulsating direct current* vibrating at the same audio frequency range (16 to 20,000 cycles per second) as the voice sound waves. The strength, or *amplitude*, of this current varies constantly, depending upon the strength of the sound waves which vibrate the microphone diaphragm.

1.4 Transmitter

The transmitting station houses the equipment necessary to broadcast speech and music. Basically it consists of an *amplifier* and a *high frequency oscillator*. The amplifier is the energy

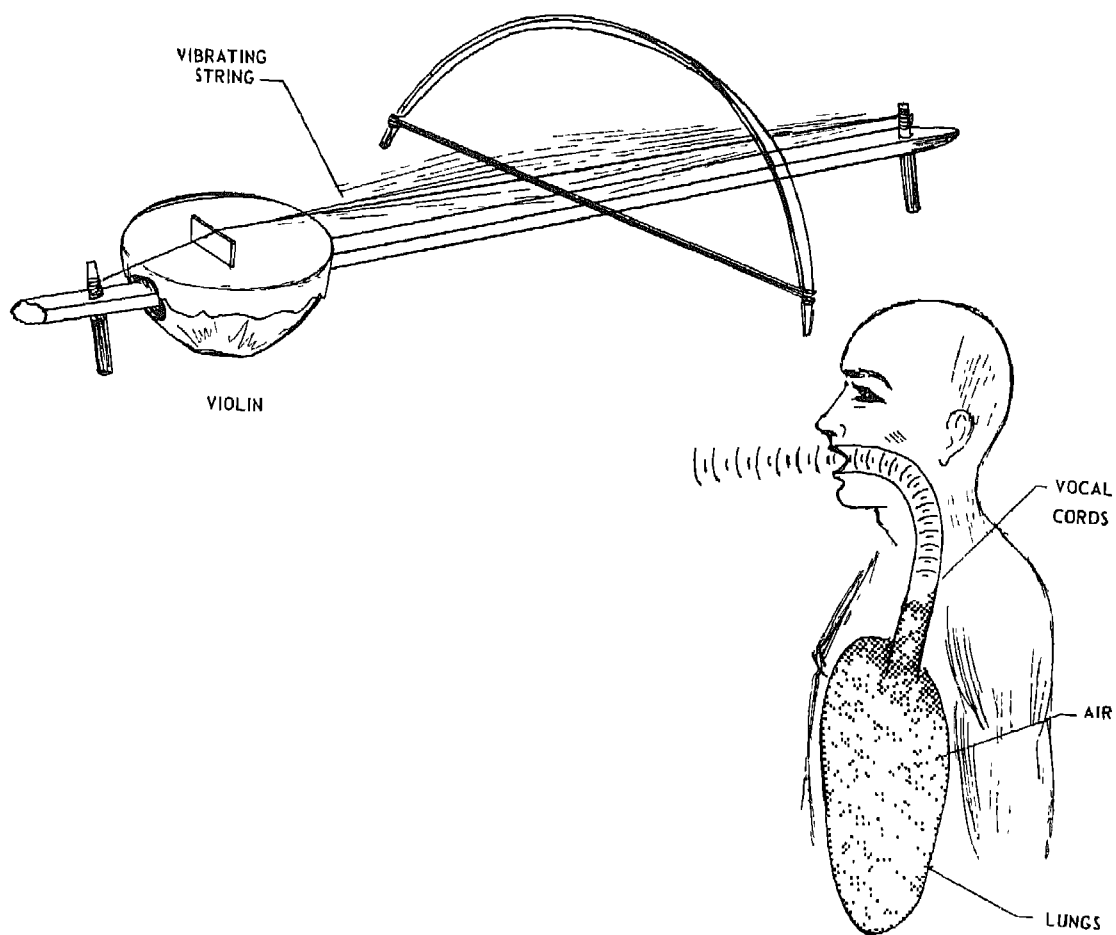


Fig. 1.2 A. Vibrating Cords Produce Sound

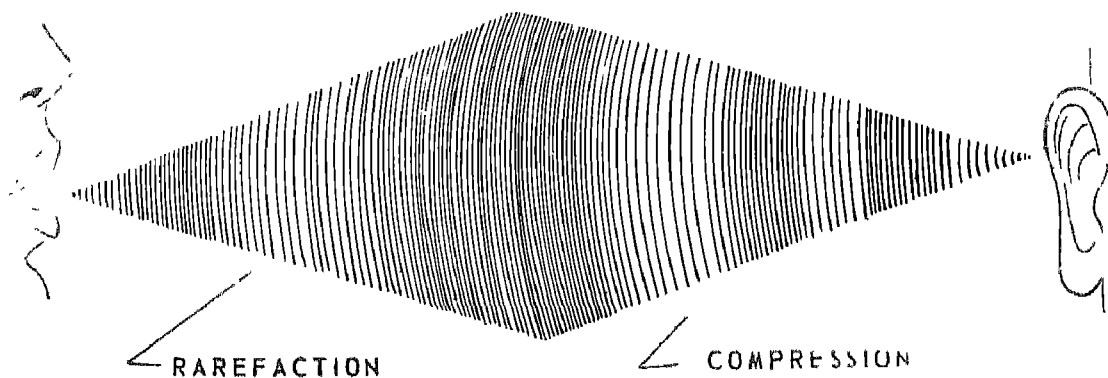


Fig. 1.2.B. Sound Waves

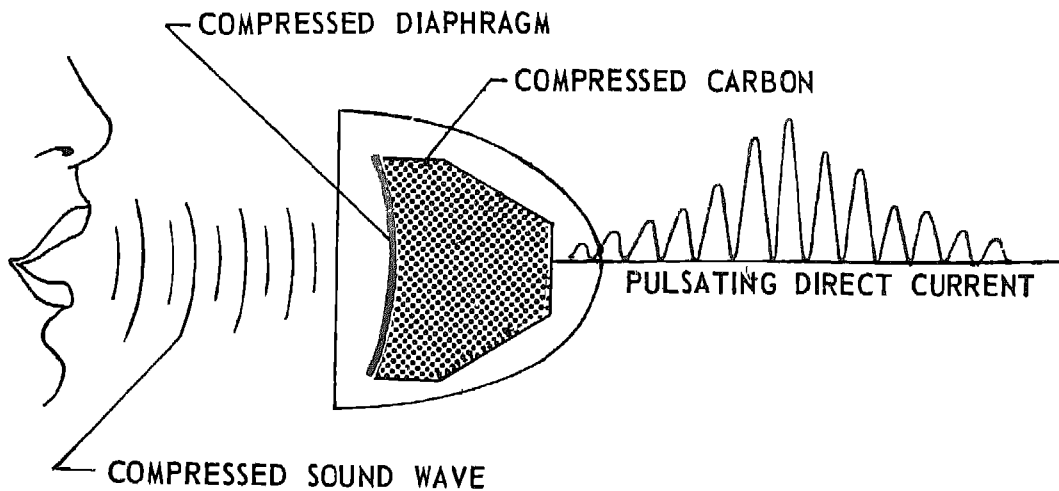
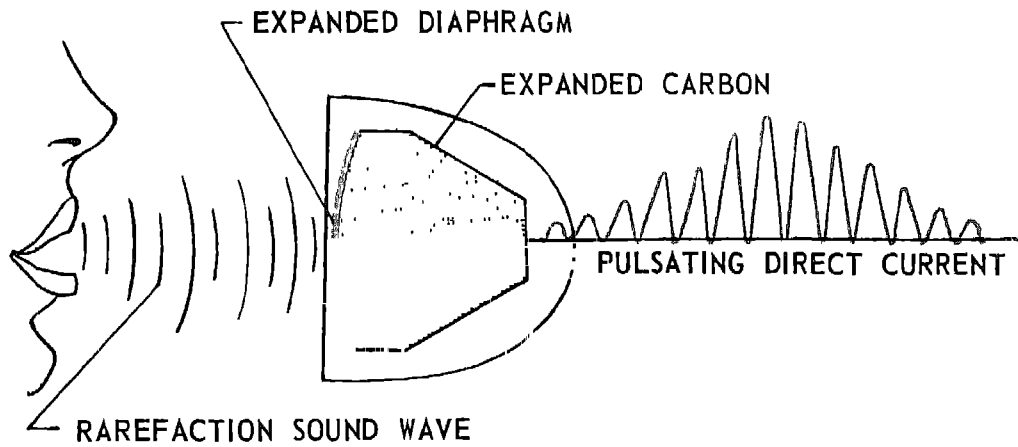


Fig. 1.3.A Crystal Microphone

source that increases the power of the signal. The high frequency oscillator causes a stream of electrons to vibrate forth and back at high fre-

quencies. The oscillator does to electricity what the vibrating vocal cords and the violin string do to sound waves.

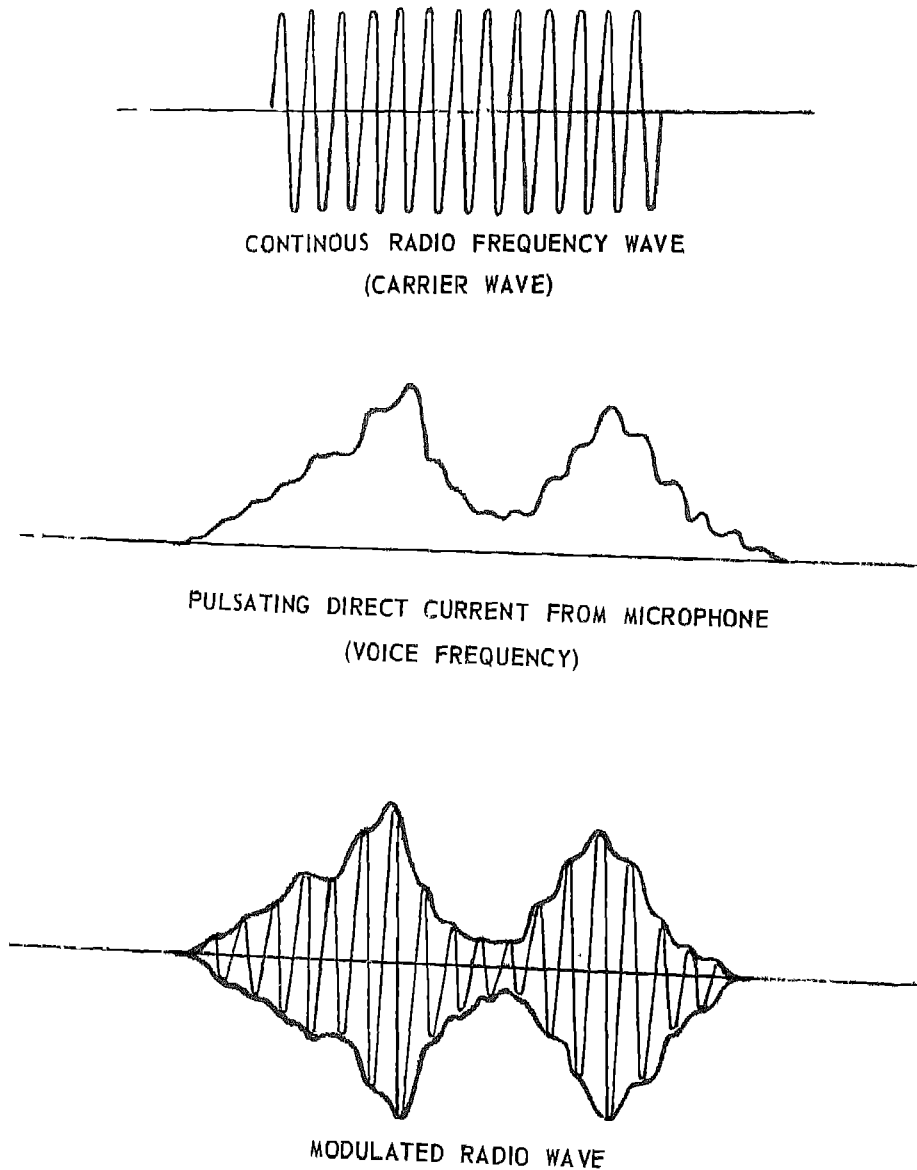


Fig. 1.4.A Radio Waves

The high frequency oscillator produces alternating current that is changing the direction of flow very rapidly. The frequencies produced by an oscillator are far above the 20,000 cycle per second frequency that the ear can hear. Broad-

casting stations that are received by standard radio receivers have assigned frequencies of 535,000 cycles per second to 1,605,000 cycles per second. Because radio frequencies have such a large number of cycles per second it is accepted practice

to express the frequency in *kilocycles* per second. A *kilo* means one thousand. Therefore, a kilocycle stands for 1,000 cycles. A broadcasting station that is assigned to operate on 760 kilocycles means that its frequency is 760,000 cycles per second. The generally accepted abbreviation used on the radio receiving dial would read 760 kilocycles.

The high frequency assigned to a broadcasting station, when produced by an oscillator, would appear visually, as shown in Figure 1.4.A, as a continuous high frequency radio wave. To this continuous high frequency radio wave is added, by a process known as *modulation*, the pulsating direct current from the microphone.

The modulated radio wave is actually a combination of the continuous radio frequency wave

and the audio frequency sound waves. The frequency of the continuous frequency radio wave never alters. However, the strength or amplitude changes (visually this would rise and fall) according to the varying direct current of the audio frequency sound waves.

1 5 Transmitter Antenna

The broadcast from the transmitter station is sent out from the transmitter antenna on *carrier waves*. The radio waves, which are actually combined with the carrier waves, travel out from the transmitter antenna in all directions. Radio waves move out from a transmitting antenna, if one could compare them visually, as shown in Figure 1.5.A, the same way that water waves move out from the point at which a stone hits the surface of water in a tank. Radio waves with their very high frequencies, however, would have many more waves represented. Radio waves travel at the, speed of light, 186,000 miles per second. Because of their great speed radio waves are received almost instantly after being transmitted.

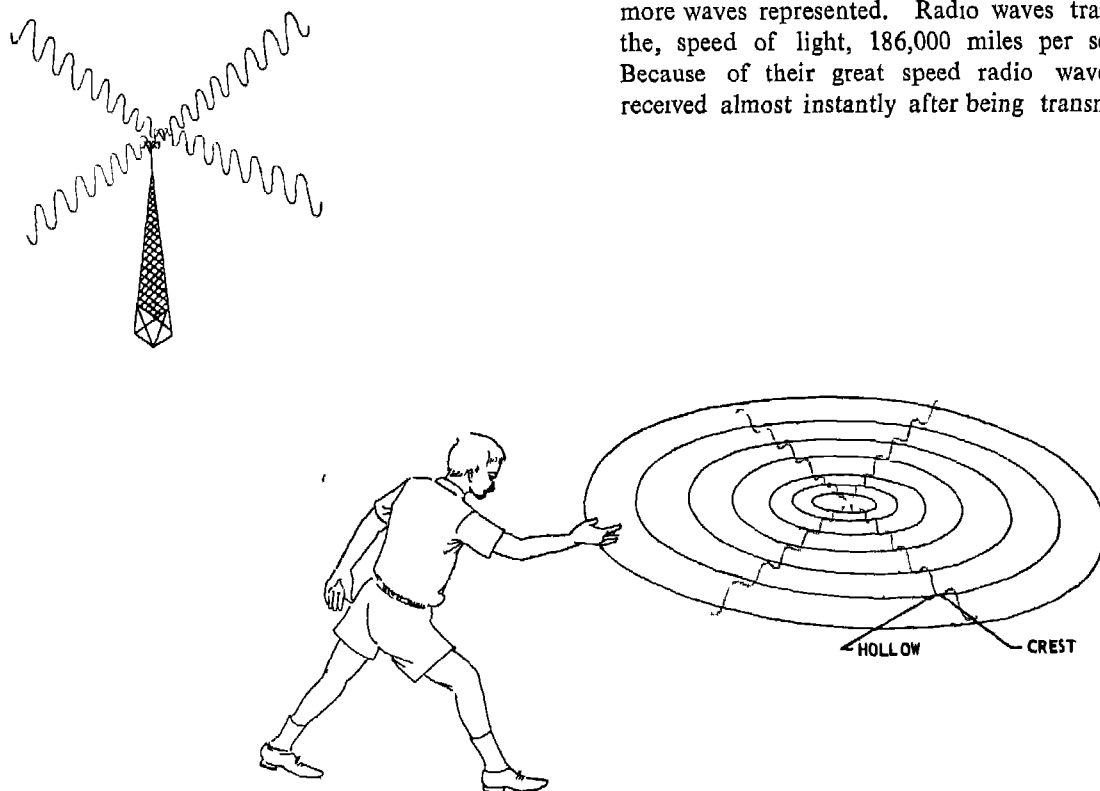


Fig. 1.5.A Radio Wave and Water Wave Comparison

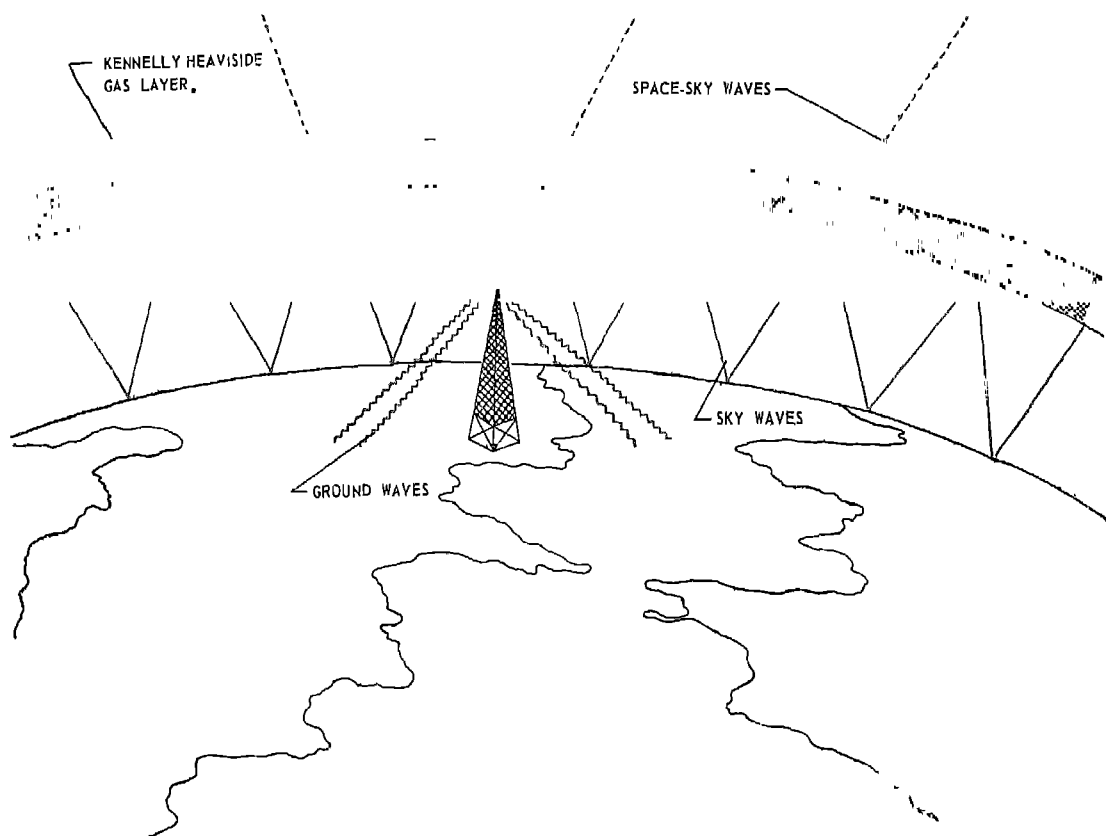


Fig. 1.5 B Radio Waves

Some of the radio waves, as shown in Figure 1.5.B, follow the surface of the earth. These are called *ground waves*. Other radio waves travel skyward. These are called *sky waves*. Some of the sky waves go straight out into space, never to return. However, most of the sky waves are reflected back to earth by a layer of ionized gas, 60 to 200 miles above the earth known as the Kennelly-Heaviside layer. The Kennelly-Heaviside layer acts like a mirror and reflects the majority of the sky waves back to earth. The sky waves reflected back to earth make possible long-range radio communication around the earth

1.6 Radio Aerial

Radio aerials are made in many different shapes. The aerial shape is selected to serve most

efficiently the radio with which it is to be used. A good radio aerial that will serve a simple radio well is a 18 gauge enamel coated, copper wire, at least 75 feet long, strung on insulators between two poles. The lead in wire should be soldered near one end of the aerial. For protection purposes against lightning, a lightning arrester should be connected to the lead-in-wire near the house. A bolt of lightning that may strike an aerial would be led into the ground instead of entering the house.

Carrier-radio waves strike the aerial, as shown in Figure 1.6.A, follow the lead-in wire to the headset and then into the ground. When the radio waves hit the aerial, a very weak alternating current begins to flow in the aerial wire. The alternating current is a faint stream of electrons that flow up

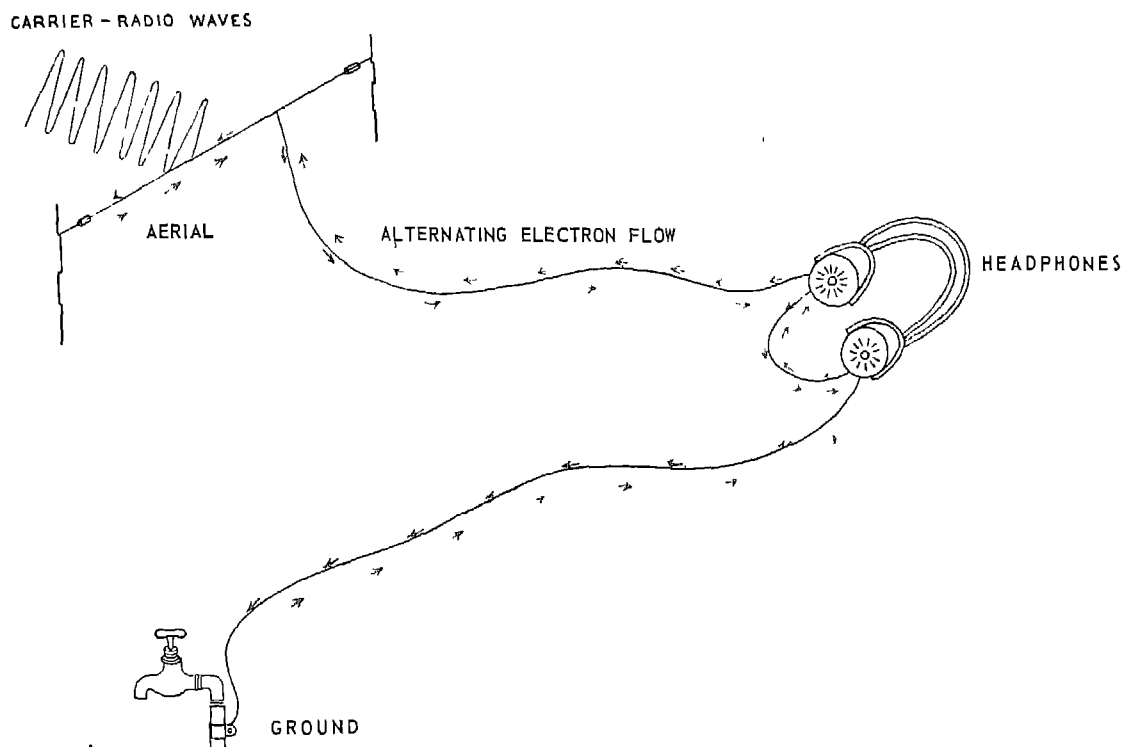


Fig. 1.6.A Aerial Ground Circuit

and down between the aerial and the ground. The *aerial ground circuit* is what gives the radio its life. You can hear clicks in the headset if you make and break the ground circuit. This proves that you are hearing the effects of the radio waves' energy. This is the same radio wave energy that is being produced at the broadcasting station.

2. FUNCTION OF THE TUNER IN A RADIO

The simplest radio receiver, called a crystal set, consists of a *tuner* and a *detector*.

Many radio waves of different frequencies strike the aerial and follow the lead-in wire to the radio receiver. The tuner is capable of select-

ing the one radio wave frequency you want to hear and rejecting all the others.

2.1 Tuner Coil

The tuner is a coil of wire, as shown in Figure 2.1 A, with a sliding piece of metal (station selector) that comes in contact with each turn of wire on the coil. By moving the station selector along the coil the length of the wire in the coil can be decreased or increased. When the station selector is set on the coil for a small number of turns of wire, a high frequency broadcasting station is tuned in. When the station selector is set on the coil for a large number of turns of wire, a low frequency broadcasting station is tuned in.

The faint stream of electrons flowing in the aerial follow the lead-in wire to the tuning coil.

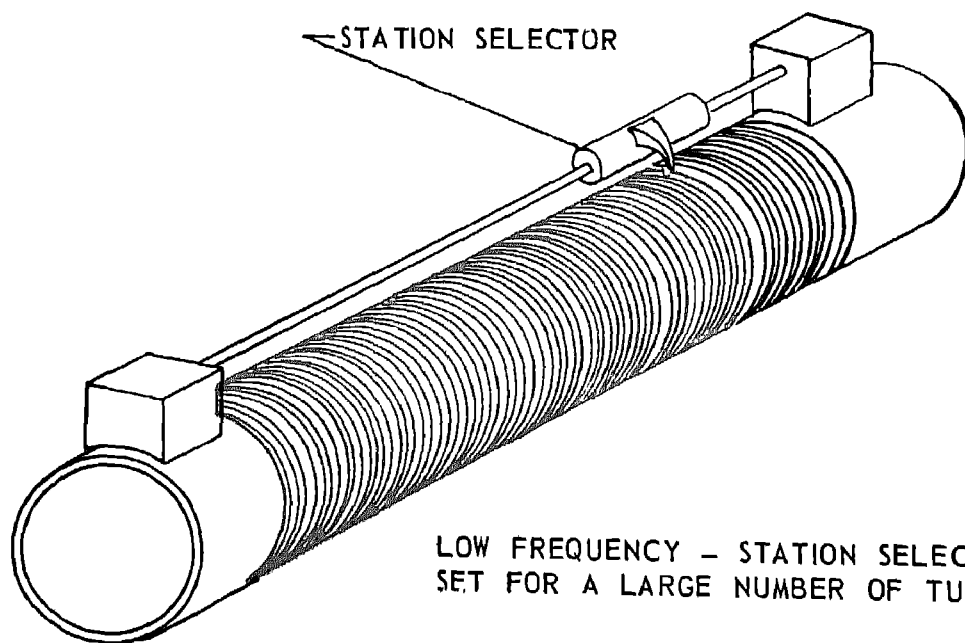
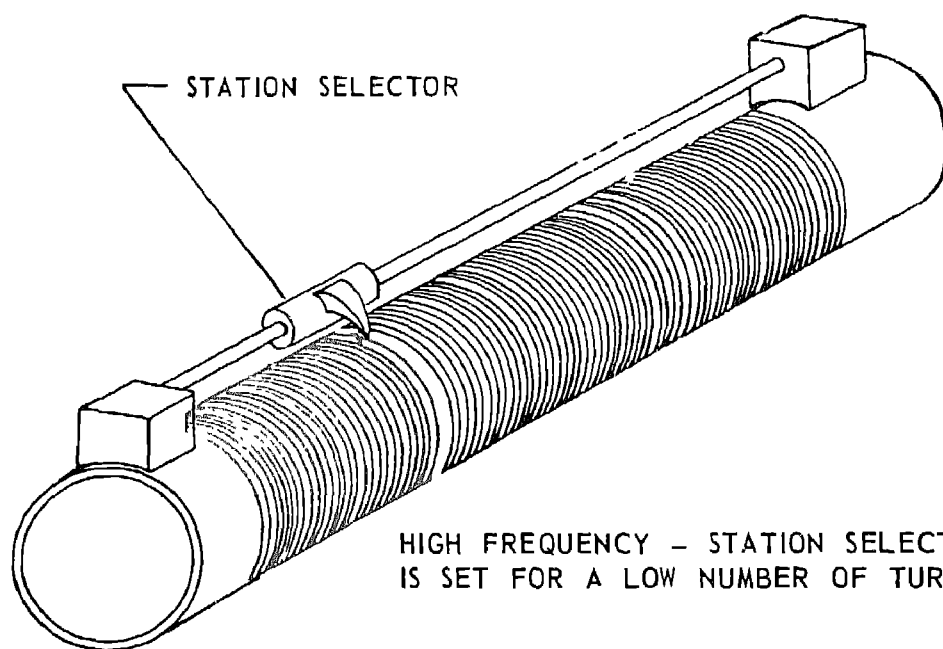


Fig. 2.1.A Tuner Coil

The tuning coil with its many turns of wire tends to resist the flow of electrons. The resistance to the flow of electrons can be varied according to where the station selector is set. When the station selector is set on the coil for a small number of turns of wire, the resistance is decreased.

Therefore, the flow of electrons will oscillate through the coil quicker. When the station selector is set on the coil for a large number of turns of wire, the resistance is increased. Therefore, the flow of electrons will take longer to oscillate through the coil.

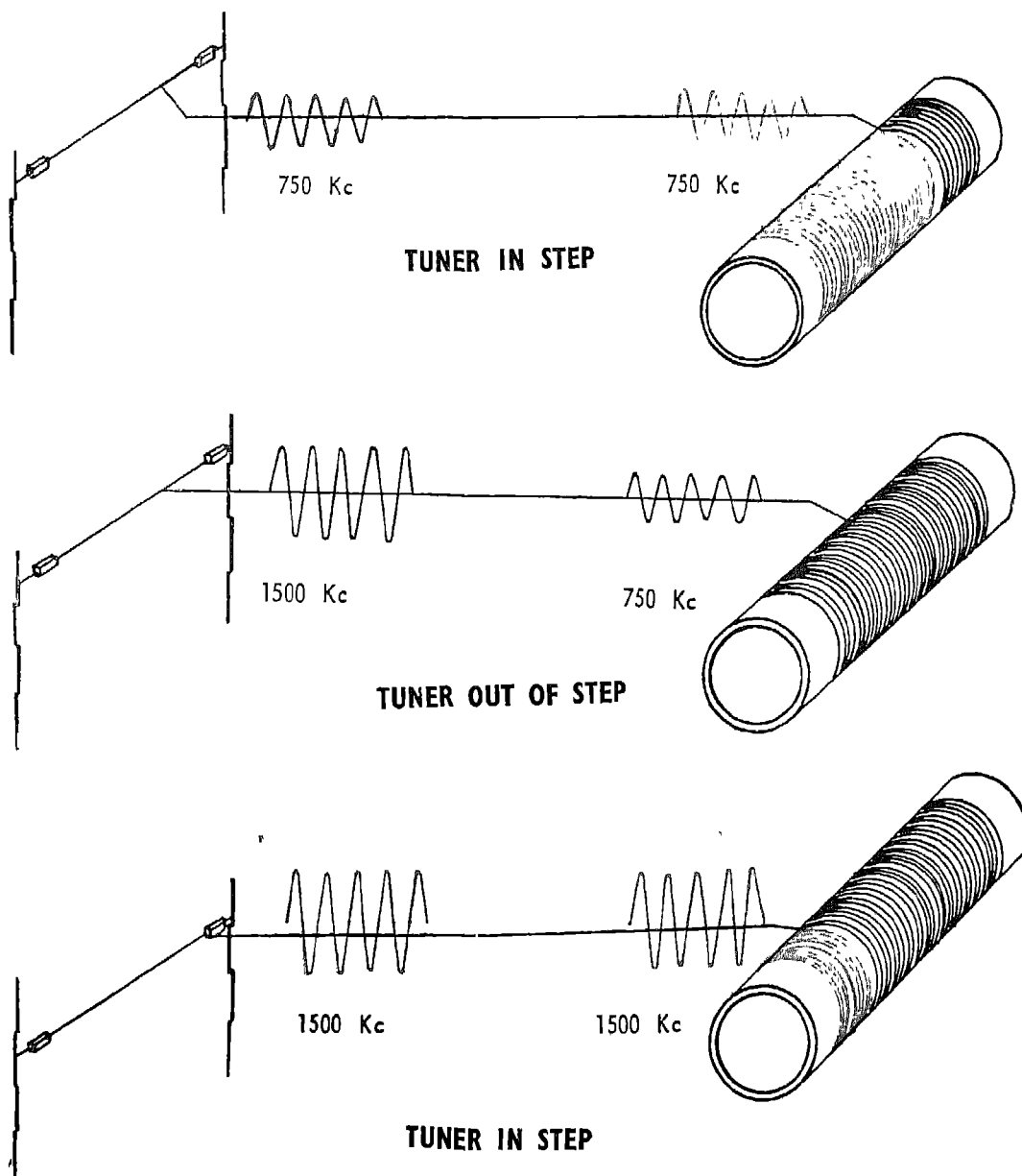
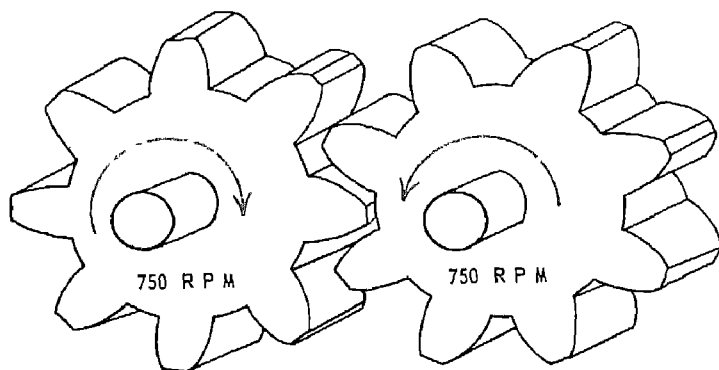
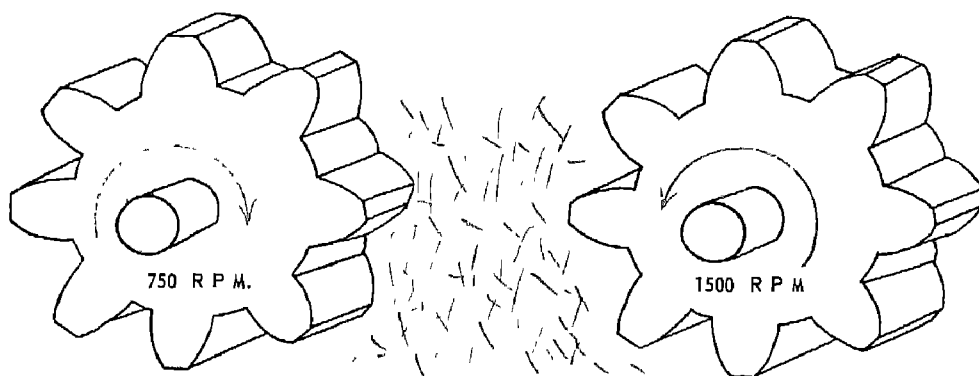
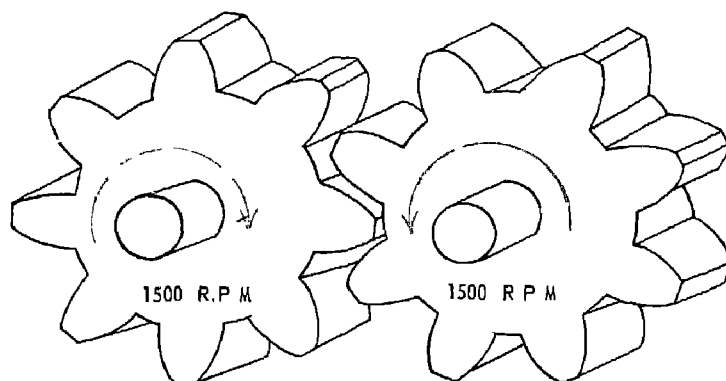


Fig. 2.2.A Tuner Coil Station Selector

**MESHED GEARS (IN STEP)****MESHED GEARS (OUT OF STEP)****MESHED GEARS (IN STEP)****Fig. 2.2.B Radio Tuner Compared to Gears**

2.2 Tuner Coil Station Selection

The faint stream of electrons flowing back and forth between the aerial and the tuning coil is oscillating at the same frequency as when it was produced by the high frequency oscillator at the broadcasting station. Therefore, if a 750 kilocycle frequency of oscillation radio wave is coming in the aerial, as shown in Figure 2.2. A, the station selector is set on the tuning coil to accept this frequency of oscillation. All frequencies from other broadcasting stations are resisted because they are out of step with this 750 kilocycles frequency of oscillation. If a 1500 kilocycles frequency of oscillation radio wave coming in the aerial is desired, the station selector is set on the tuning coil to accept this frequency of oscillation. All frequencies from other broadcasting stations are resisted because they are out of step with this 1500 kilocycles frequency of oscillation.

Tune in on (tuner) means, as the name implies, that you adjust (get-in-step) with the station you want to hear. Although many broadcasting stations are bombarding the aerial with their assigned frequencies of oscillation, the tuner gets in step only with the flow of electrons from the station you select.

One might compare the station selector to the meshing of gears as shown in Figure 2.2. B. Consider radio wave frequency of oscillation, if it could be visualized, the same as revolutions per minute. Two gears, revolving at 750 R.P.M. each could be meshed because they would be

turning (in step with each other) at the same rate of speed. Two gears revolving at 1500 R.P.M. each could be meshed because they would be turning (in step with each other) at the same rate of speed. However, the 750 R.P.M. and the 1500 R.P.M. gears, nor any others, could not be meshed because they are turning (out of step) at different revolutions per minute.

3. FUNCTION OF THE DETECTOR IN A RADIO

3.1 Crystal Detector

The frequency of oscillation selected by the tuner reaches the detector in the radio receiver, where the modulated radio wave is separated into its component parts

- (1) The continuous radio frequency wave.
- (2) The audio frequency sound wave.

The detector, as shown in Figure 3.1. A, actually separates the alternating electrical impulses of the continuous radio frequency wave from the pulsating direct current impulses of the audio frequency sound waves.

The earliest form of radio detector was the crystal. Therefore, the name crystal set was given to this form of radio reception. Certain crystals such as silicon, galena, and germanium possess the characteristic of conducting electric current in one direction only. The crystal acts like a one-way street that permits traffic to flow in one direction.

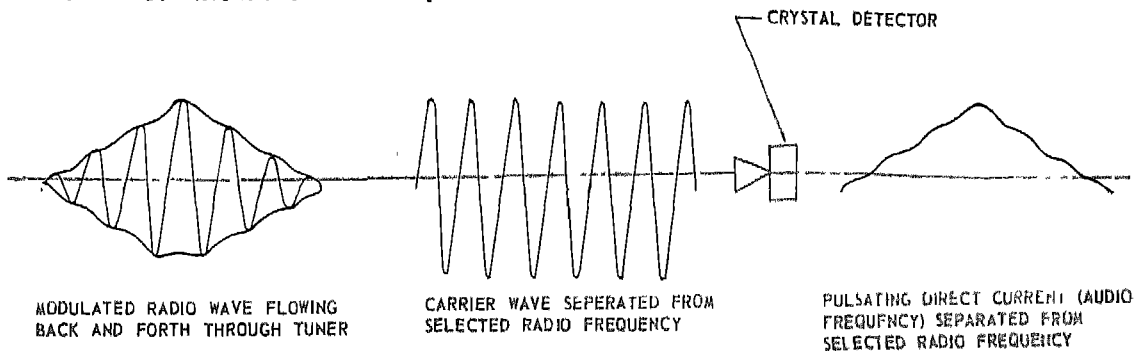


Fig. 3 8 A Separation of Pulsating Direct Current from Carrier Waves

and resists it in the opposite direction. The electrical impulses flowing through the aerial and tuner coil are alternating current impulses. When they reach the detector it resists the alternating current, permitting current to flow through in only one direction. Alternating current that is changed into direct current is said to be rectified. The direct current is the same pulsating direct current as the audio frequency sound waves produced by the microphone

3.2 Fixed Crystal Detector

The galena crystal was one of the earliest forms of radio detector used. Considerable adjusting was necessary with a wire called a *cat whisker*, in order to find the most sensitive spot on the crystal for satisfactory rectification. The modern version of the galena is the germanium crystal in a sealed container, as shown in Figure

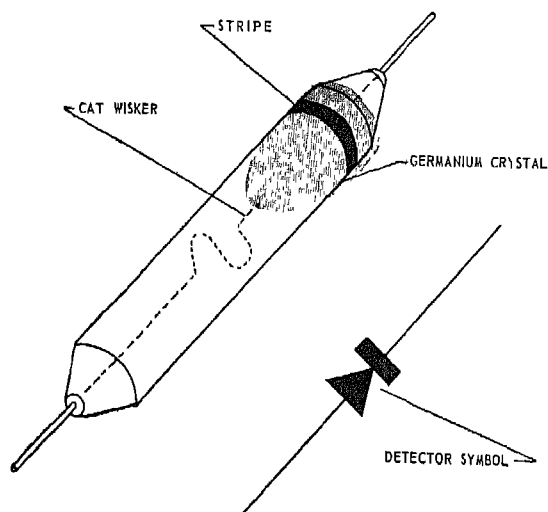


Fig. 3.2.A Fixed Crystal Detector

3.2. A, with the sensitive spot fixed during manufacture. The electrons flow through it in only one direction; from the wire 'cat whisker' to the germanium crystal. A stripe, usually painted around the crystal diode, indicates the direction of current flow. In a schematic view of a crystal detector, the arrow points in the direction of the current flow.

4. HEADPHONES

Headphones are very sensitive listening devices. They are capable of operating with a very weak signal, and they have the advantage of providing listening in private.

4.1 Magnetic Headphones

Headphones, as shown in Figure 4.1. A operate on the principle of the electromagnet. A thin metal diaphragm is mounted in front of the electromagnet. The pulsating direct current from the detector causes a build-up and collapse of the magnetic field in the coils. When the direct pulsating current produces a high current in the magnetic coils, the thin metal diaphragm is attracted towards the magnet. When the current is low, the thin metal diaphragm will spring back to its original position. The in and out movements of the thin metal diaphragm will conform to the variations created by the pulsating direct current in the electromagnet. The headphone is an excellent example of the application of the principle of the electromagnet as the actual force that converts electrical energy into mechanical energy.

4.2 Headphones to Sound Waves

The current flowing through the electromagnets in the headphones is varying according to the pulsating direct current from the detector. Therefore, the thin metal diaphragm, being very sensitive, conforms to all of these electrical impulses. These rapid vibrations of the diaphragm cause rapid variations in the air pressure surrounding the headphones. The variations in the air pressure, which are in step with the diaphragm, reproduce as sound waves. As the thin metal diaphragm is pulled in, rarefaction pressure area is created. As the thin metal disc moves outward, compression (high pressure is created). These sound waves vibrate within the audio frequencies of 16 to 20,000 cycles per second. The ear, sensitive to vibrations within the same frequencies of 16 to 20,000 cycles per second, is capable of hearing these sound waves.

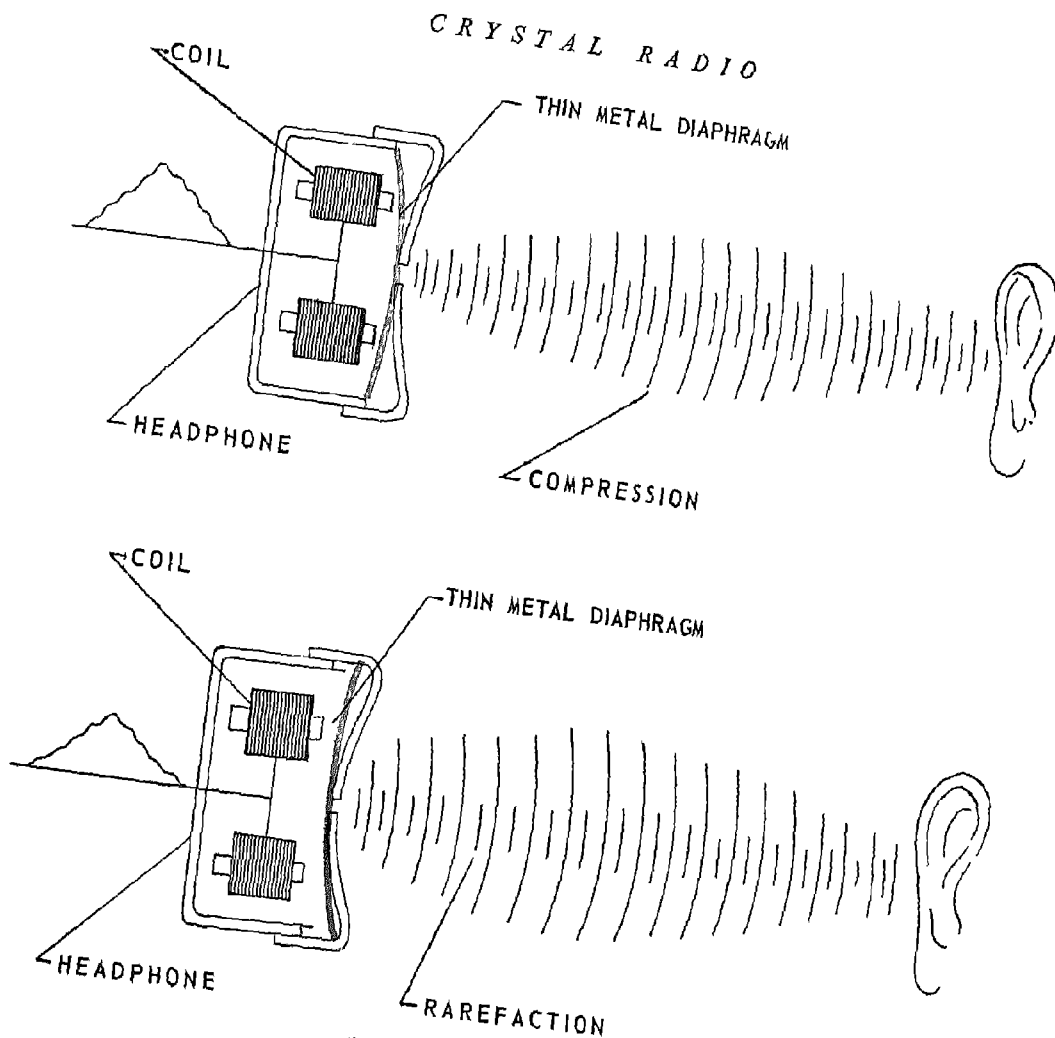


Fig. 4.1.A Magnetic Headphones

5. CRYSTAL RADIO EXPERIMENT

MATERIALS

5.1 Wood

The crystal radio base, coil mount and selector knob are made of wood. Because of its softness, wood provides the easiest method of mounting the radio parts. It is also a non-conductive material and, therefore, acts as an insulator between the radio parts.

5.2 Metal

The station selector can be made from several different types of metal. Availability of the metal should be the determining factor. Any type of metal that has some springiness to it, such as brass, tin, or galvanized steel sheet iron will work. Spring brass, because it is a good conductor of electricity, retains its spring tension, takes a high polish and does not corrode, and makes the best sliding electrical contact between the station selector and the coil.

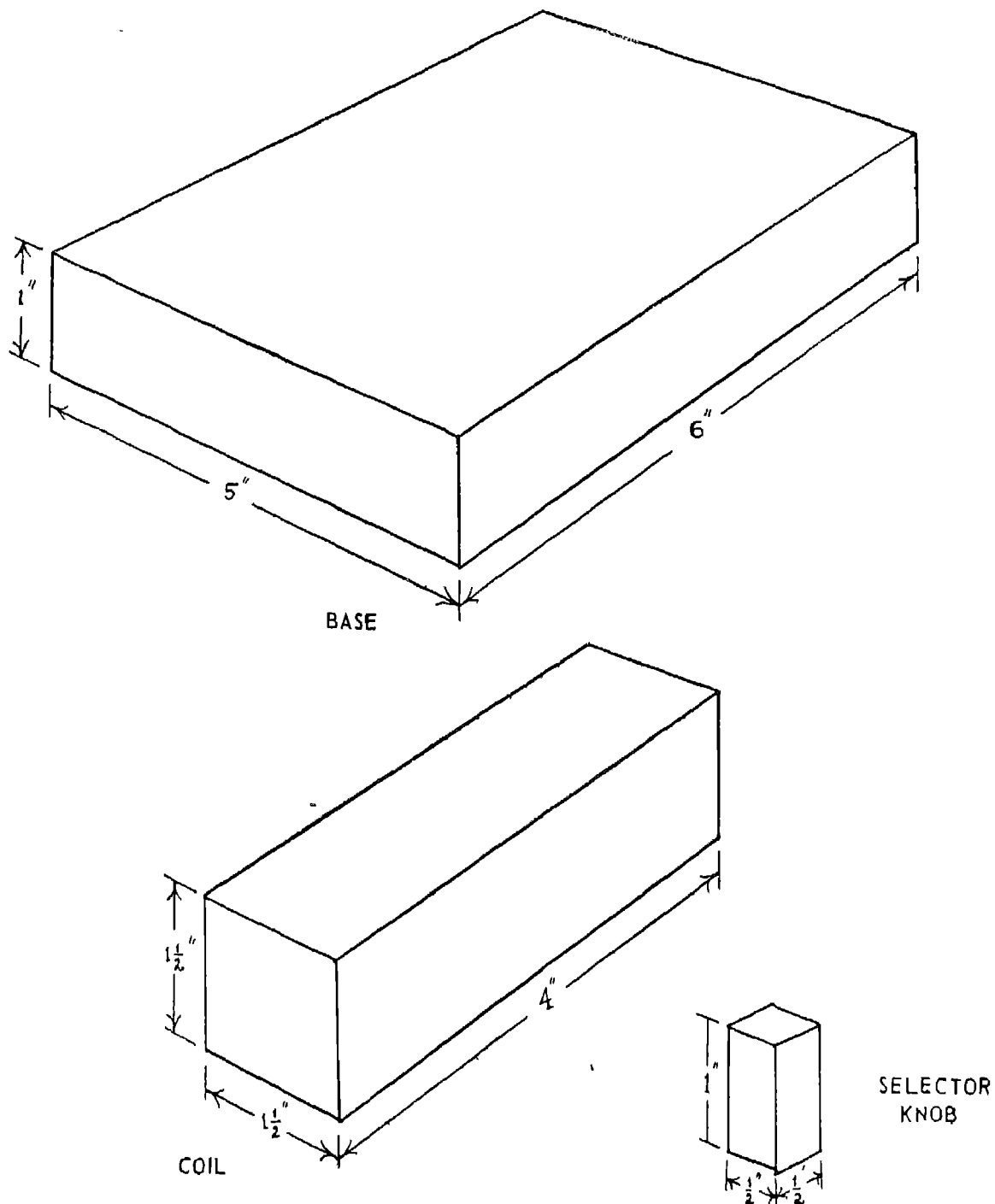


Fig. 5.6.A Wood Parts

5.3 Crystal

A germanium crystal diode is recommended for the detector. The germanium crystal diode offers the advantage of being manufactured as a sealed unit with assured sensitivity.

5.4 Electrical Connectors

Good electrical connections are required for the aerial, ground, and headphones. Ceramic connectors with set screws are very suitable. However, any type of a binding post or clip will work.

5.5 Fasteners

Brass screws, such as round head 1/2"—No. 4, and 2"—No. 8 are very suitable for mount-

ing the radio parts on the wood base

Brass washers, to fit the screws, should be used for a good electrical connection on the station selector and as spacers under the coil.

Brass screws and washers are recommended, in preference to steel, because they resist corrosion and make good electrical connectors.

PROCEDURE

5.6 Wood Parts

Make the wood base, as shown in Figure 5.6.A, to the approximate size of 1" × 5" × 6".

The coil mount should be 1-1/2" × 1-1/2" × 4". The shape and distance around the coil is important. A round or square shape may be used. A

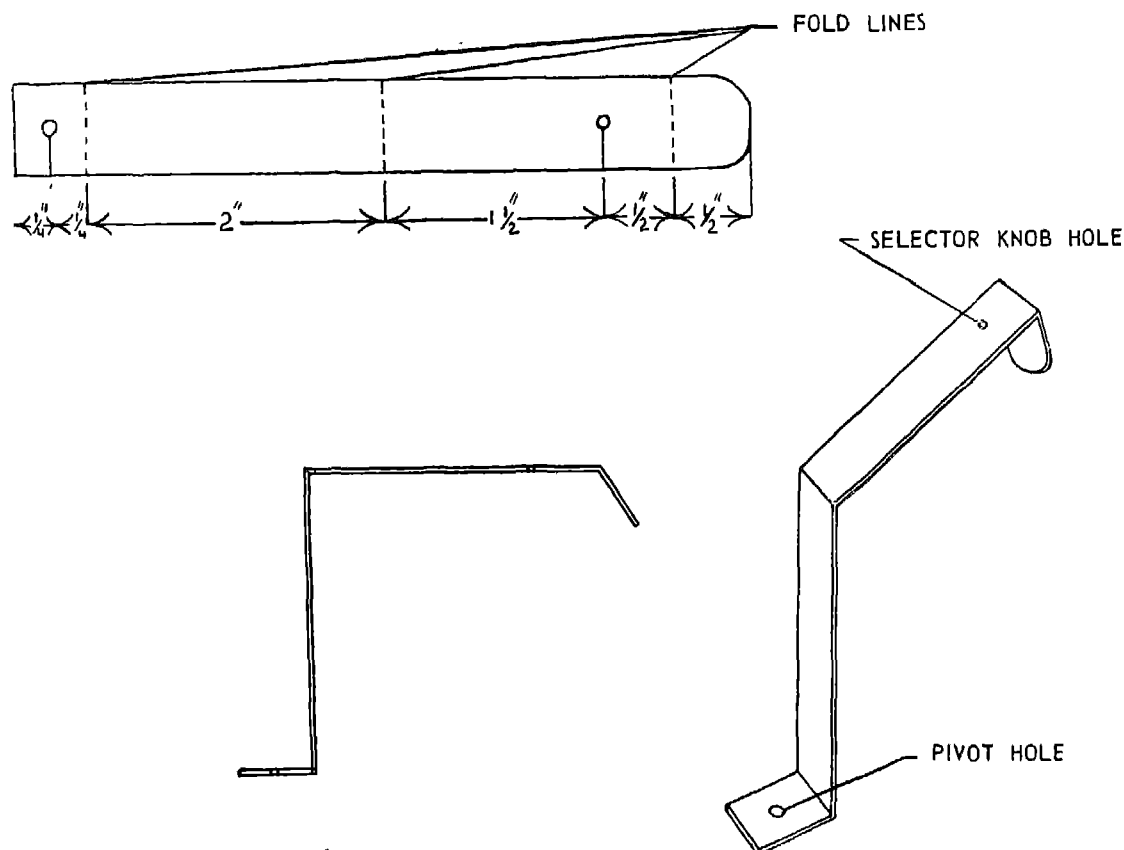


Fig. 5.7.A Station Selector

round coil offers the best radio reception; however, a square coil is easier to construct and mount. If different measurements are used, be sure the distance around the coil circumference is at least 4", because this will affect the total length of the wire wound around the coil mount. Drill two mounting holes along a centre line approximately 1/4" in from each end. Drill two small holes, for starting and ending the wire coil, near each edge, approximately 1/2" in from the ends.

The selector knob is a small piece of wood approximately 1/2" x 1/2" x 1" long. The purpose of the selector knob is to avoid, during station selection, direct finger contact with the station selector.

5.7 Station Selector

Cut the station selector metal, as shown in Figure 5.7.A, approximately 1/2" wide and 5" long. Drill a pilot hole, the size of the shank of the 1/2" No. 4 brass screw, 1/4" from one end of the metal. Drill a selector knob mounting hole, for a 1/2" No. 4 screw, 1" from the opposite end.

Round and polish the end of the station selector to the approximate shape shown in the drawing. The round end of the station selector must make good electrical contact as it rides over the coiled wire.

Bend the station selector, on the fold lines, to conform to the approximate shape shown in the drawing. The bent end of the station selector will provide the spring tension necessary to keep the station selector in contact with the coil.

5.8 Coil

Approximately one hundred and twenty five turns of No. 24 enamel coated, copper wire, as shown in Figure 5.8.A, is needed to wind the coil. The distance around the wood coil mount, being approximately 6", means that the total length of the wire used for the coil is about 750".

Slip the enamel coated wire through the

left hand small hole along the edge of the wood coil mount. Allow about 4" of the wire to extend beyond the edge of the wood coil mount. Later on, the wire will serve as an electrical connection.

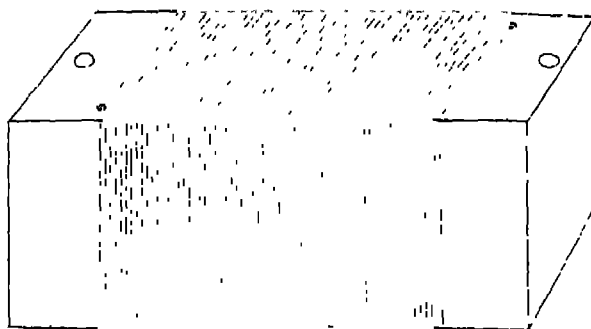


Fig 5.8.A A Coil

Remove all kinks and bends from the wire by smoothing between the fingers. Wrap the wire neatly and tightly, keeping each turn snug against the other. Wrap enough wire on the wood coil mount to fill the entire distance between the two small wire securing holes. Slip the end of the wire through the right hand small hole along the edge of the wood coil mount. The coil wire protruding from the right hand hole may be cut short because no connection is required at this end of the wire.

5.9 Assembly

Centre the coil on the wood base approximately 1/4" in from the edge. Locate the correct screw positions on the base by marking through the holes in the wood coil mount. Drill anchor holes for each screw position. Mount the coil clear of the wood base, by using several brass washers as spaces between the coil and wood base.

Drill an anchor hole for a 1/2" No. 4 screw in one end of the selector knob. Fasten the selector knob securely to the station selector from the bottom side with a screw.

Draw a centre line, from in front of the coil, the length of the wood base. Position the station

selector along the centre line so that the round end of the station selector makes an arc completely across the top of the coil. Locate the correct screw position on the base by marking through the pivot hole of the station selector. Drill an anchor hole for the screw.

The pivot point of the station selector must have a good electrical connection and yet be free enough to slide across the wire coil. To ensure the best possible electric connection, as shown in Figure 5.9.A, the wire should be soldered to a brass

make a good electrical connection and yet, be free enough to allow the station selector to be moved across the wire coil.

The electrical contact between the station selector and the coil must be good. Locate the exact shape of the arc by pressing down firmly on the end of the station selector while moving it back and forth across the top of the coil. Carefully with a knife, the tang of a file, or some other pointed instrument, scrap the enamelled insulation from the wire along the station selector contact

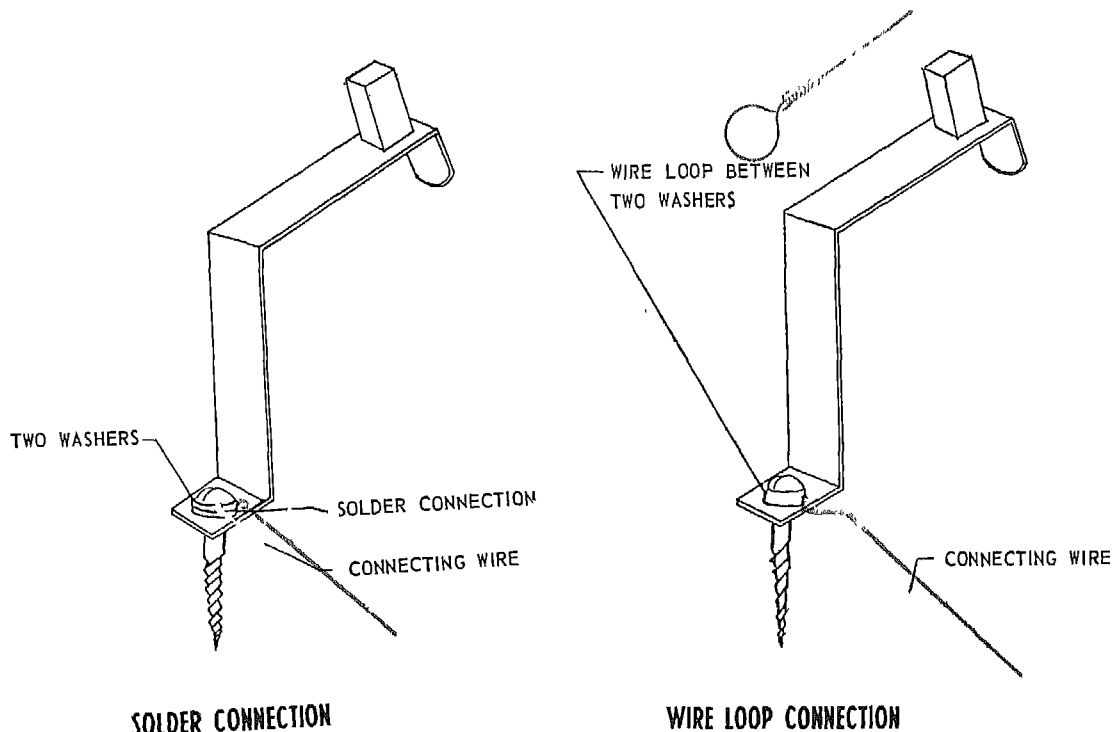


Fig. 5.9.A Station Selector Connection

washer. However, if solder is not available, form a loop in the connecting wire, the size of the screw shank, and wrap the end tightly around the main strand. Place a washer on each side of the wire loop and slip them over the mounting screw. Place a washer underneath the station selector and fasten the mounting screw into the anchor hole. The screw should be tightened snugly enough to

curve. All of the insulation along the curve must be removed to ensure a good electrical contact between the station selector and each turn of wire on the coil.

Fasten the aerial, ground, and headphone connectors into position. Two wire ceramic connectors, binding posts or clips work very well.

Fasten them securely with screws, through their mounting holes, to the wood base.

One end of the germanium crystal diode, as shown in the schematic diagram of Fig. 5.9.B, is fastened to the wire coil lead and the other end to the headphone. It is advisable, depending upon the type of connections made, that the crystal diode be soldered. However, in soldering a crystal diode extreme precaution must be taken. A

crystal diode can be permanently damaged by a slight amount of overheating. When soldering a diode lead, always grasp it with a pair of pliers placed between the diode and the solder connection. The pliers protect the diode by absorbing the heat and thus prevent heat from passing on into the diode.

When connecting the crystal diode be sure to observe the colour code indicating the direction of

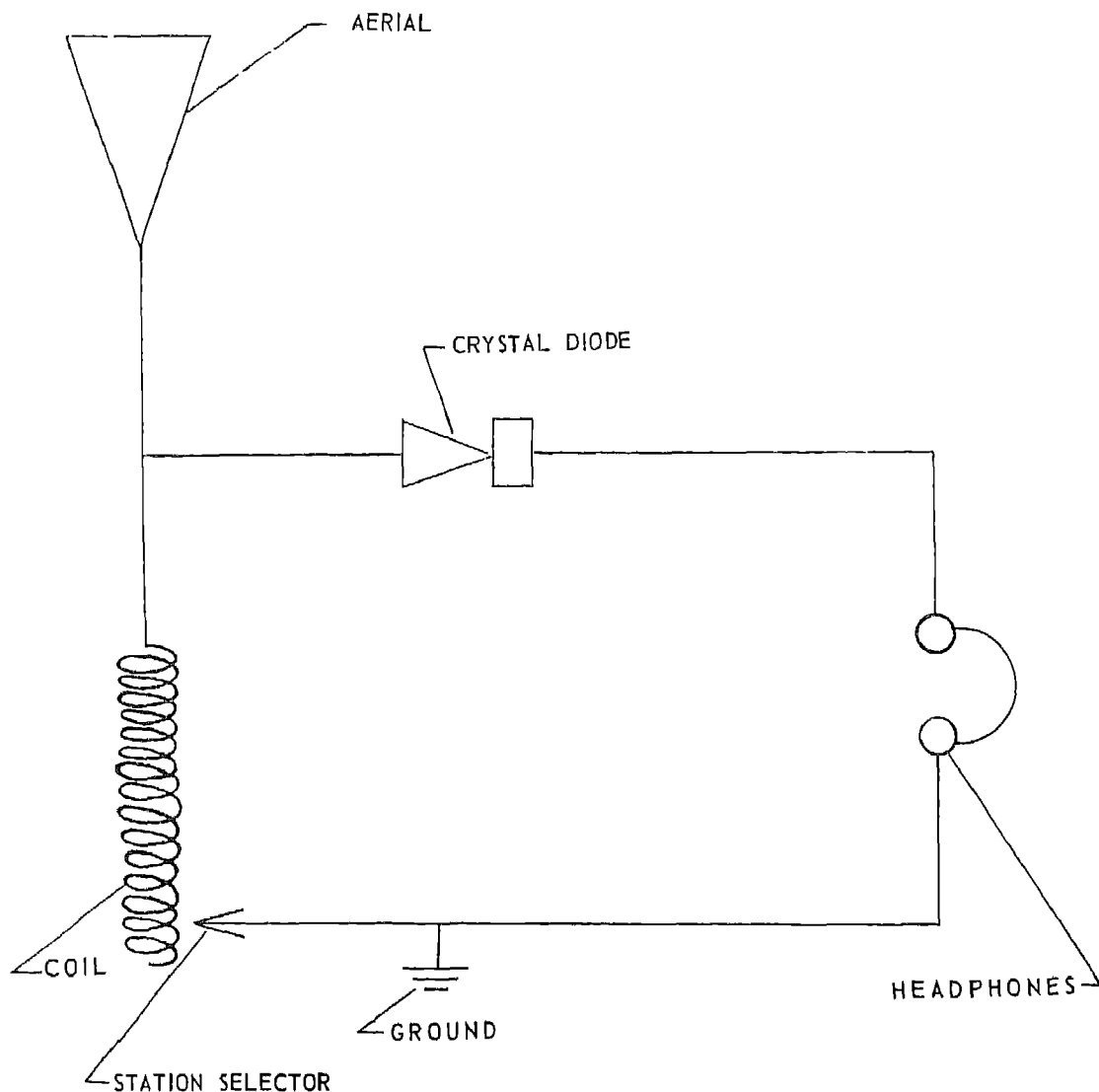


Fig. 5.9.B Schematic Diagram of Crystal Set

current flow through the crystal. Notice that the schematic diagram indicates that the direction of current flow is towards the headphone connection.

The two wire ceramic connectors offer a simple method of wiring the crystal set. However, notice that the crystal set is wired exactly the same in both the schematic and pictorial drawings. Strip all of the enamelled insulation from the ends of the wire connections. Insert the ends in the ceramic connectors, as shown in Figure 5.9.C, and tighten the set screws. If the thin wires do not hold securely in the ceramic connectors, bend the ends over double and then re-

tighten the set screws. The double thickness of the wire will provide sufficient holding power for the set screws.

5.10 Operation

Connect the aerial lead-in wire into the ceramic connector hole marked 'ANT.' Connect a ground lead from a water pipe into the ceramic connector hole marked 'GRND.' Connect a headphone lead into each ceramic connector hole marked 'HP.' To pick up a broadcast move the station selector slowly across the top of the coil.

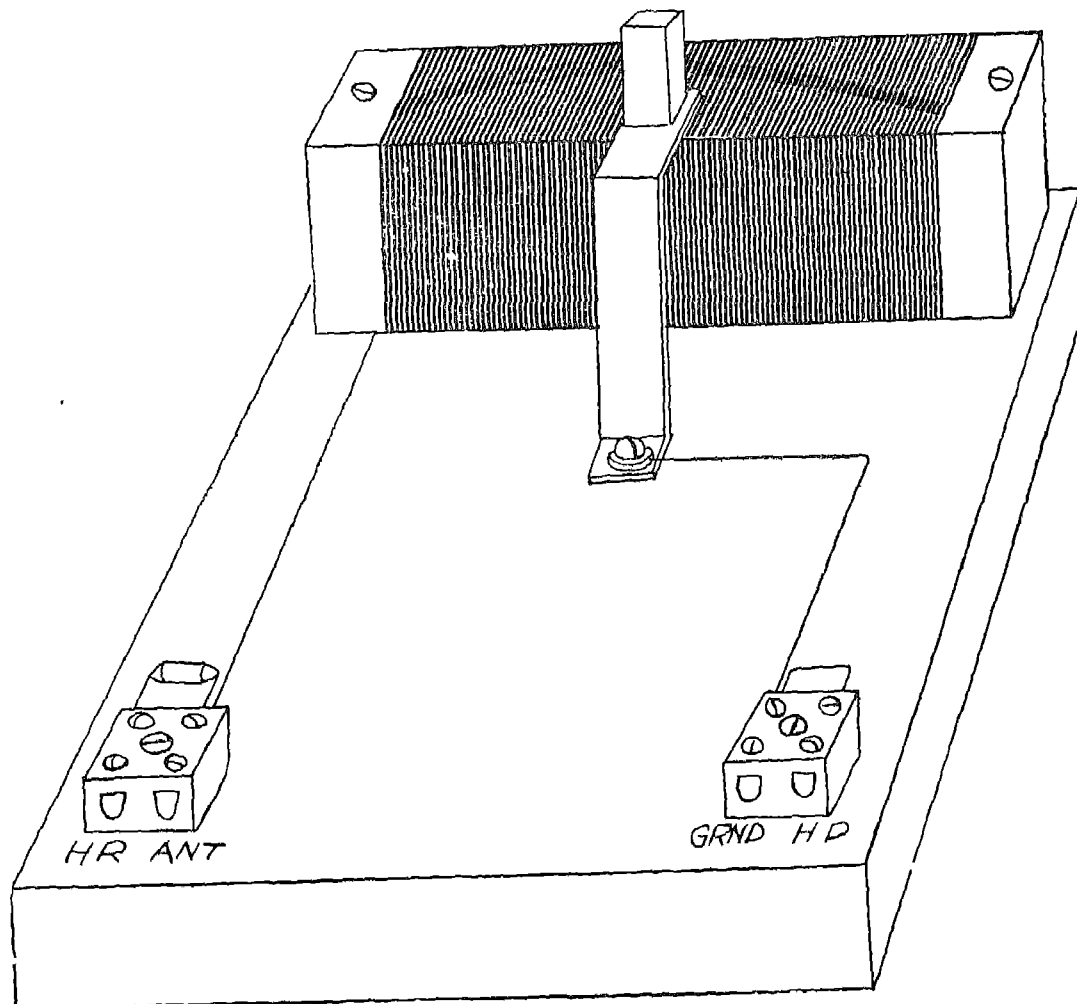


Fig. 5.9 C Pictorial Diagram of Crystal Set

STUDY QUESTIONS

The Crystal Radio Unit contained many important ideas and practices of electricity that you should understand. The following questions have been listed as types that your instructor will use for internal grading. Therefore, review this unit well until you are able to answer all the questions easily and correctly. If you are unable to understand the questions or find the answers, please see your instructor for help.

ESSAY QUESTIONS

Essay questions should be designed to provide the student with the opportunity to express, in writing, technical information on a limited subject. Each student can be assigned a different topic, or the same topic. The advantage of different topics is that it will provide the teacher with a broader reaction to all of the materials studied.

1. Describe the principle of radio communication.
2. Describe the function of the tuner in a radio.
3. Describe the function of the detector in a radio.
4. Describe the principle of operation of the microphone.
5. Describe the principle of operation of the magnetic headphones.

TRUE AND FALSE QUESTIONS

The following statements are either TRUE or FALSE. Fill in the blank at the left of the number with a + sign for the true questions and a O sign for false questions.

- _____ 1. The decompressed air of a sound wave, which is a low pressure area, is called compression.
- _____ 2. Variations in air pressure cause the metal diaphragm of a microphone to vibrate in step with the sound waves.
- _____ 3. When there is no air pressure on the metal diaphragm of a microphone the carbon powder is loose. This permits a strong current flow.

_____ 4. The amplifier is the energy source that increases the power of the signal.

_____ 5. The high frequency oscillator causes a stream of electrons to vibrate forth and back at high frequencies.

_____ 6. The frequency of a continuous radio wave changes, however, the strength or amplitude never alters.

_____ 7. When the station selector is set on the tuner coil for a small number of turns of wire, the resistance is increased.

_____ 8. If a 1000 kilocycle frequency of oscillation radio wave is coming in the station selector is set on the tuning coil to accept this frequency of oscillation.

_____ 9. The detector actually separates the alternating electrical impulses of the continuous radio frequency wave from the pulsating direct current impulses of the audio frequency sound waves.

_____ 10. The germanium crystal was one of the earliest forms of radio detector used.

COMPLETION QUESTIONS

The following statements will all be true with the addition of one or more words. Fill in the blank at the left of the number with the correct word or words that completes the sentence.

_____ 1. Radio communication is important in a highly technical world because of its direct contact by voice whether between.. .., ..., or... .. stations.

_____ 2. The. in the transmitting station is the energy source that increases the power of the signal.

_____ 3. Radio frequencies have such a large number of cycles per second that it is accepted practice to express the frequency in per second.

_____ 4. waves which are actually combined with waves, travel out from the transmitter aerial in all directions.

5. Most sky waves are reflected back to earth by a layer of ionized gas above the earth, known as the

6 For protection against lightning striking a house a . . . should be connected to the aerial lead-in wire.

7. The simplest radio receiver, called a crystal set, consists of a . . . and a . . .

8 When the station selector is set on the coil for a small number of turns of wire, a . . . broadcasting station is tuned in.

9. The faint stream of electrons flowing back and forth between the aerial and the tuning coil is oscillating at the same frequency as when it was produced by the at the broadcasting station.

10. Alternating current that is changed into direct current by a crystal is said to be

of cycles per second to cycles per second.

- (4) 335,000 to 605,000
- (2) 535,000 to 6,105,000
- (3) 335,000 to 5,105,000
- (4) 535,000 to 1,605,000

5. The electrical impulses in headphones are changed into sound waves by rapid vibrations of the metal diaphragm vibrating within the audio frequencies of to cycles per second

- (1) 12,000 to 16,000
- (2) 16,000 to 20,000
- (3) 20,000 to 24,000
- (4) 24 000 to 28,000

PROBLEM QUESTIONS

Problem questions should be designed to provide the student with the opportunity to express in writing, technical information on a limited problem. Each student can be assigned a different problem or the same problem. The advantage of different problems is that it will provide the teacher with a broader reaction to all of the materials studied. Students should be required to show the correct procedure for solving the problem and include all calculations

MULTIPLE CHOICE QUESTIONS

The following statements will all be true with the addition of one or more words. Place the number of the word, or group of words, that correctly completes the sentence in the blank to the left of the question number.

1. Carrier waves travel through space at the speed of light which is . . . miles per second.

- (1) 166,000 (3) 186,000
- (2) 176,000 (4) 196,000

2. The human ear can hear sound waves that vibrate at audio frequencies of . . . to . . . cycle per second.

- (1) 12,000 to 16,000
- (2) 16,000 to 20,000
- (3) 20,000 to 24,000
- (4) 24,000 to 28,000

3. Sound waves travel through the air at a speed of about feet per second

- (1) 1,100 (3) 3,100
- (2) 2,100 (4) 4,100

4. Broadcasting stations that are received by standard radio receivers have assigned frequencies

1. Schematic Diagram. Draw a schematic diagram of a crystal radio and briefly describe the function of each part.
2. Pictorial Diagram. Draw a pictorial diagram of a crystal radio and briefly describe the function of each part
3. Mechanical Trouble Shooting. List five mechanical defects that may effect the efficient operation of a crystal set. Describe how to make the necessary repairs or adjustments.
4. Electrical Trouble Shooting. List five electrical defects that may effect the efficient operation of a crystal set. Describe how to correct the electrical difficulties.

R E F E R E N C E S

- Buban, Peter and Schmit, Marshall L., *Understanding Electricity and Electronics*. New York : Mc-Graw-Hill Book Company Inc., 1963 .
- Gerrish, Howard H , *Electricity*. Chicago : Goodheart-Wilcox Company, Inc., 1961.
- Jones, E.W., *General Electricity*. Illinois : Bloomington : McKnight & McKnight Publishing Company, 1954.
- Steinberg, William B., and Ford, Walter B., *Electricity and Electronics*. Chicago : American Technical Society, 1961.
- Turner, Rufus P., *Basic Electricity*. New York : Holt, Rinehart and Winston, 1963.
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A P P E N D I X A

SELECTED ELECTRICAL DEFINITIONS FROM INDIAN STANDARDS

IS : 732—1963

2. TERMINOLOGY

- 2.1 ACCESSORY—Any device, associated with wiring and electrical appliance of an installation, for example, a switch, a fuse, a plug, a socket-outlet, a lamp-holder, or a ceiling rose.
- 2.2 APPARATUS—Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.
- 2.4 CABLE—A length of single-insulated conductor (solid or stranded), or two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.
- 2.6 CABLE, FLEXIBLE—A cable containing one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.
- 2.14 CIRCUIT—An arrangement of a conductor or conductors for the purpose of conveying energy and forming a system or a branch of a system.
- 2.15 CIRCUIT-BREAKER—A device, capable of making and breaking the circuit under all conditions, and unless specified otherwise so designed as to break the current automatically under abnormal conditions.
- 2.17 CLEAT—An insulated non-combustible support normally used for insulated cable,
- 2.19 CONDUCTOR, BARE—A conductor not covered with insulating material. See Definition 3.9 for general requirements for conductors.
- 2.21 CONDUCTOR, INSULATED—A conductor adequately covered with insulating material of such quality and thickness as to prevent danger. See Definition 3.9 for general requirements for conductors.
- 2.22 CONDUCTOR OF A CABLE OR CORE—The conducting portion consisting of a single wire or group of wires, assembled together and in contact with each other or connected in parallel. See definition 3.9 for general requirements for conductors.
- 2.23 CONNECTOR—A mechanical clamp shrouded in insulating material for connecting the conductor of a cable or of a flexible cord to that of another cable or of another flexible cord.
- 2.27 CORD, FLEXIBLE—A flexible cable having conductor of small cross-sectional areas. Two flexible cords twisted together are known as 'Twin Flexible Cord'.
- 2.34 DISTRIBUTION FUSE-BOARD—An assemblage of parts including one or more fuses arranged for the distribution of electrical energy to final sub-circuits or to other distribution fuse-boards.
- 2.35 EARTH—A connection to the general mass of earth by means of an earth electrode. An object is said to be 'earthed' when it is electrically connected to an earth electrode; and a conductor is said to be 'solidly

earthed' when it is electrically connected, to an earth electrode without a fuse switch, circuit breaker, resistance or impedance in the earth connection

- 2.38 EARTHING LEAD—The final conductor by which the connection to the earth electrode is made
- 2.43 FUSE—A device that, by the fusion of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted when the current through it exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device
- 2.46 INSULATION—Suitable non-conducting material, enclosing, surrounding or supporting a conductor.
- 2.55 SOCKET-OUTLET AND PLUG—A device consisting of two portions for easily connecting portable lighting fittings and other current-using appliances to the supply. The socket-outlet is designed as a fixed member and the plug portion carries two or more metal contacts which connect with corresponding metal contacts in the socket portion.
- 2.56 SWITCH—A manually operated device for closing and opening or for changing the connection of a circuit.
- 2.59 VOLTAGE, LOW—The voltage which does not normally exceeds 250 volts.
- 2.60 VOLTAGE, MEDIUM—The voltage which normally exceeds 250 volts but does not exceed 650 volts.
- 2.61 VOLTAGE, HIGH—The voltage which normally exceeds 650 volts.

3. GENERAL REQUIREMENTS

- 3.9 CONDUCTORS—All conductors shall be of

copper or aluminium. The conductor for final sub-circuit wiring shall have a nominal cross sectional area not less than 1.00 mm² copper and 1.50 mm² aluminium. The cross-sectional area of the conductor for power wiring shall be not less than 1.50 mm² copper and 2.50 mm² aluminium. The minimum cross-sectional area of a conductor of flexible cord shall be 0.40 mm². In the case of a power circuit, the wiring shall be designed for the load which it is supposed to carry

Note—Various precautions to be taken and techniques to be employed in using aluminium conductor cables have been detailed in Appendix D.

- 3.12 RATING OF LAMP, FAN AND SOCKET-OUTLET POINTS—In estimating the current to be carried by any conductor, incandescent lamps shall be rated at 60 watts, unless otherwise specified. Ceiling fans, table fans and ordinary socket-outlet points shall be rated at 60 watts, fluorescent lamps at 40 watts and power socket-outlet points at 1,000 watts, unless the actual values are known or specified. Exhaust fans, if any, shall be rated according to their capacity.

4. RECEPTION AND DISTRIBUTION OF MAIN SUPPLY

- 4.7 FIXING TO WALLS AND CEILINGS—Plugs for ordinary walls or ceilings shall be of well-seasoned teak or other approved hardwood not less than 5 cm long and 2.5 cm square on the inner end and 2 cm square on the outer end. They shall be cemented into walls to within 6.5 mm of the surface, the remainder being finished according to the nature of the surface with plaster or lime punning.

5. FITTINGS AND ACCESSORIES

5.2 SOCKET-OUTLETS AND PLUGS

- 5.2.2 Every socket-outlet shall be controlled by a switch which shall preferably be located immediately adjacent thereto or combined therewith.
- 5.2.3 The switch controlling the socket-outlet shall be on the live side of the line.
- 5.2.4 Ordinary socket-outlet may be fixed at any convenient place above 23 cm from the floor level, and shall be away from danger of mechanical injury.

NOTE : In situations where a socket-outlet is accessible to children, it is necessary to install an interlocked plug and socket or alternatively, automatically screened by the withdrawal of the plug.

5.3 LIGHTING FITTINGS

- 5.3.1 Every lighting fitting shall be controlled by a switch and where control at more than one point is necessary by as many two-way and intermediate switches as there are control points. Lights, fans and socket-outlets shall be so located as to provide maximum comfort to the occupant and to enable him to utilize the electricity in the most economical manner.

6 METHODS OF INTERNAL WIRING

6.2 WOOD CASING WIRING SYSTEM

- 6.2.1 *General*—This system of wiring is suitable for low voltage installation where vulcanized rubber insulated cables, plastic insulated cables and/or other approved insulated cables shall be used in the wiring work and carried within wood casing enclosure. Wood casing wiring system shall not be used in

damp places and/or ill-ventilated places, unless suitable precautions are taken.

- 6.2.2 *Material and Pattern of Casing*—All casing shall be of first class seasoned teak wood or any other approved hardwood, free from knots, shakes, saps, or other defects, all sides planed with smooth finish and all sides well varnished both inside and outside with pure shellac varnish. The casing shall have grooved body with beaded or plain moulded cover as desired

- 6.2.6 *Attachment of Capping*—All capping, shall be attached to the casing (after all insulated wires are laid inside grooves) by round-head screws (preferably of brass) fixed on edges and screwed to outer walls of the casing at an interval not exceeding 15 cm crosswise (that is, 30 cm between two successive screws on each side) for all sizes up to 64/mm casing and capping; for sizes above 64 mm similar additional round-head screws shall be fixed on the centre-wall (or alternative walls in cases of 3 grooves) at an interval of 45 cm.

Note : Care shall be taken in fixing screws on cappings so that they do not pierce through the walls of casing and damage the insulation.

- 6.2.7 *Joints in Casing and Capping*—Casing and capping shall be run in lengths as long as possible. All joints shall be scarfed or cut diagonally in longitudinal section and shall be smoothed down by fitting to make joints a very close fit as far as possible. They shall be secured at joints with two or more screws as would be necessary. Joints in capping shall not overlap those in the casing

6.3 TOUGH RUBBER-SHEATHED OR PVC-SHEATHED WIRING SYSTEM

- 6.3.3 *Link Clips*—Only tinned brass link clips shall be used. Link clips shall be so arranged that one single clip shall not hold more than two twin-core TRS or PVC-sheathed cables up to 200 mm² above which a single clip shall hold a single twin-core cable. The clips shall be fixed on varnished wood battens with brass pins or brass screws and spaced at intervals at 10 cm in the case of horizontal runs and 15 cm in the case of vertical runs. For the wiring and runs of mains exposed to heat and rain, clips specially made for outdoor use from a durable metal, resistance to weather and atmospheric corrosion, shall be used.

7. EARTHING

7.3 GENERAL RULES APPLYING TO ALL SYSTEMS OF EARTHING

- 7.3.3 *Earthing Conductor*—Every earthing conductor shall be of high conductivity copper and shall be either stranded, flat strips or circular or rectangular bar. Protection against mechanical injury shall be provided where necessary. Bare conductor shall be protected against corrosion. Galvanized solid iron or steel wire or rod or any other suitable approved material may be used provided the conductivity is not less than the copper earthing conductor. The cross-sectional area of copper earthing conductor shall be not smaller than half that of the largest current-carrying conductor subject to an upper limit of 65 mm². However, for equipment of capacity larger than 750 KVA, the size shall be determined as in Appendix A of IS : 1886-1961 Code of Practice for Installation and Maintenance of Transformers.

GLOSSARY OF TERMS

- AMPERE**
- , The unit of current flow through an electrical circuit.
- , **RATING** Refers to the amount of amperes an electric motor should use under normal operating conditions.
- AMPLIFIER** A mechanical device which increases the strength of an electric signal.
- AMPLITUDE** The highest value reached by voltage, current, or power during any given cycle.
- ANCHOR HOLE** A small hole bored into a piece of wood that permits easier turning of the wood screw but ensures sufficient holding power. The anchor hole is equal to the root diameter of the screw.
- ARMATURE** The revolving part of a motor that reacts to the electrical energy and converts it into mechanical energy.
- AUDIO-FREQUENCY** Sound of frequency that the ear can hear.
- CERAMIC BUSH** A ceramic insulator, of the grommet type, which protects electric wires from rubbing against metal openings.
- CIRCUIT**
- , **BRANCH** That part of a wiring system that divides into smaller independent circuits.
- , **CLOSED** A complete path followed by an electric current passing from its source through a succession of conductors and back to its starting point.
- , **LIGHT** The path taken by an electric current in the light circuit, passing from its source, through a succession of conductors, accessories and apparatus, back to its starting point.
- , **OPEN** A potentially complete path, which could be followed by electric current passing from its source through a succession of conductors and back to its starting point, is broken somewhere along the path.
- , **PARALLEL** An arrangement where several pieces of electrical apparatus are connected across two wires of the power line.
- , **POWER** The path taken by an electric current in the power circuit, passing from its source, through a succession of conductors, accessories and apparatus, back to its starting point.
- , **SERIES** The connection of the parts of a circuit from end to end so that the current feeding one must pass through the others along a single path.
- , **SHORT** The accidental connection of two sides of a circuit through which nearly all of the current will flow.
- CONDUCTANCE CAPACITY** The capacity for which a conductor is rated to carry an electric current safely.
- CONDUIT** A pipe used as a protective container for electric wires.
- CURRENT**
- , **PULSATING DIRECT** A current flowing in one direction but not of the same amplitude.

- , **ALTERNATING** An electric current which reverses in direction at rapid regular intervals, usually 100 times per second.
- CRYSTAL DIODE** A fixed crystal which is used as a rectifier, since it will pass current only in one direction and not in the other.
- CYCLE** The number of times that alternating current (AC) makes a complete cycle (reverses in direction) in one second.
- DAMPER** A flat plate in the flue of a stove used to regulate the draft.
- DETECTOR** The stage in a receiver for converting inaudible high frequency radio signals into audible low frequency audio signals that can be heard by the human ear.
- DIAPHRAGM** A thin disk, usually made of sheet metal, flexible enough to respond to sound wave vibrations.
- DISTRIBUTION PANEL** The central point in a house from which light and power branches out to all rooms
- DRAFT** A movement of air, as in a flue, caused by hot air rising and cool air moving in to take its place.
- ELECTRIC HEATING ELEMENT** A predetermined length of resistance wire, usually in coiled form as found in a hot plate, in which electrical energy is transformed into heat energy.
- ELECTRIC TEST PANEL** A conveniently mounted panel, with various types of testing instruments, for determining whether electrical accessories and apparatus are in perfect working order.
- ELECTRICITY** A form of energy present when electrons flow through a circuit.
- ELECTRON** The smallest particle of electricity.
- FIELD COIL** The insulated wire wound around the field magnets or pole pieces of an electric motor.
- FLUE** An enclosed passage, such as a chimney for a stove, through which currents of air and gases may escape.
- FORMULA** A statement of symbols arranged to indicate the mathematical operations necessary for the solution of a problem.
- FILAMENT** A thin wire, as in a lamp, in which electrical energy is transformed into heat energy
- FUSE** An electrical safety device to prevent excessive current from causing damage to a circuit. It consists of a short length of conducting metal which melts at a certain heat and thereby breaks the circuit.
- , **Box** A metal box adapted for the safe mounting of fuses in an accessible manner
- , **CARRIER** A ceramic insulator designed to conveniently hold a piece of fuse wire.
- GENERATOR** A general term applied to machines by which mechanical energy is transformed into electrical energy.
- GUTTI** A wood plug-buried below the surface of a masonry wall, to which various types of wood fittings can be securely mounted
- HIGH FREQUENCY OSCILLATOR** The electrical stage in a circuit whereby a very high number of vibratory cycles are produced.

HORSEPOWER (H.P.) The rating in terms of a mechanical unit of power, that determines the size of an electric motor.

INCANDESCENT LAMP A lamp in which a thin wire, when heated while hot, gives off light.

KENNELLY HEAVISIDE A layer of ionized gas, 60 to 200 miles above the earth's surface, which acts as a reflecting medium for radio waves.

KILOWATTHOUR (KWH) A kilowatthour is one thousand watt-hours.

MAGNETIC

ELECTROMAGNET A temporary magnet produced by passing an electric current through an insulated wire conductor coiled around a soft iron core.

MAGNETISM A property in certain metals that exerts invisible forces of attraction and repulsion.

PERMANENT MAGNET A metal such as steel, which when magnetized permanently, has the property of consistently attracting and repelling particles.

METER

AMMETER An instrument for determining the quantity of current flow in an electric circuit.

MULTIMETER A voltmeter, ammeter and ohmmeter combined in one unit.

OHMMETER An instrument for determining the number of ohms of the resistance being measured.

VOLTMETER An instrument for determining the potential voltage between two points.

———, **WATTHOUR** An instrument that records the amount of power consumed in watthour.

MICROPHONE A mechanical device that changes sound waves into electrical impulses.

MOTOR

———, **ELECTRIC** A machine that transforms electrical energy into mechanical energy.

———, **INDUCTION** A motor where all the source current flows through the stator coils and induces current in the rotor, because there is no connection between the stator and the rotor.

———, **SERIES** A motor where all the current flows through the field coils and the armature, because they are connected in series. The speed varies with the load.

———, **SHUNT** A motor where part of the current flows through the field coils and part through the armature, because they are connected in the parallel. The speed is constant, irrespective of variation in load.

———, **SYNCHRONOUS** An induction type alternating current motor whose speed is in proportion to the frequency of the supply current and the number of poles designed in the motor.

OHM The unit of resistance in an electrical circuit.

- OSCILLATION** It is a condition that produces electrical alternations. Actually it is like a forward and backward motion, as in vibration.
- PORCELAIN CONNECTOR** A solderless connector used where two or more wires are to be connected together.
- RADIO**
- , **COMMUNICATION** Communication from one place to another without the use of wires between them.
 - , **CRYSTAL** The simplest radio receiver, consisting of a tuning coil and a crystal detector.
 - , **RECEIVER** A combination of associated components used to receive and increase the strength of a radio signal and to reproduce it as audible sound.
- RAREFACTION** The act or process of becoming less dense.
- REVOLUTIONS PER MINUTE (R.P.M.)** The number of times a motor shaft revolves in one minute.
- RESISTANCE** The opposition offered to the flow of electric current by the conductivity of the substance through which it is flowing.
- ROTOR** The revolving part of an alternating current induction motor, in which current is induced by the the stator field coils.
- SERVICE ENTRANCE** The place where the service wires are run into a building.
- SHELF LIFE** The length of time an object can remain in storage without significant deterioration.
- SPLICES** The joining of wires together, of which three are recommended types. Pig Tail, Tap Splice, and Western Union Splice.
- SOLDERING** Soldering is the joining of two pieces of metal by another metal of lower melting temperature. This metal is temporarily transformed into fluid state for bonding purposes. The heated solder fuses with the metal pieces, joining them in a strong union.
- STATOR** The stationery part of an alternating current induction motor on which the field coils are wound,
- SWITCH** A mechanical accessory used for closing or opening the connections of an electric circuit.
- , **KNIFE** A switch with hinged blades for the moving contacts, which open or close the circuit by entering between the contact clips.
- TAPE** A narrow strip or band of flexible insulating material impregnated or coated with an adhesive compound. The three recommended types for electric insulation are friction tape, rubber tape, and plastic tape.
- TRANSMISSION** The act, operation or process by which power is passed (transmitted) from one place to another.
- TRANSMITTER** The complete broadcasting system from the pick-up microphone to the aerial that transmits the radio wave.
- TROUBLE SHOOTING** To make a calculated guess pertaining to a mechanical difficulty and then systematically isolate the exact trouble.

- TUNER** A coil of wire which can be mechanically adjusted to select a desired radio signal and reject all others.
- TURBINE** A huge water wheel built inside a casing or housing, that revolves at very high speeds by the force of falling water.
- UNDERWRITER'S KNOT** A specially designed knot, approved by the American Underwriter's Laboratory, that is used as safety device with electric wires to prevent them from being subjected to undue pull at terminal post connections.
- VIBRATION** To move forward and backward, or from side to side, or up and down in such a manner to cause a pulsing or oscillating motion.
- VOLT** The unit of pressure in an electrical circuit.
- VOLTAGE DROP** The loss of power, or potential difference between two points in a conductor.
- WATT** The unit of power in an electrical circuit.
- WAVES**
- , **GROUND** The portion of a transmitted wave which follows the earth's surface.
- , **RADIO** Invisible electronic waves that are transmitted through the air.
- , **SKY** A wave which spreads or extends by reflection from the ionosphere.
- , **SOUND** The rapid variation of air pressure caused by compressed and decompressed air.
- WIRE**
- , **EARTHING** A wire connected between the ground and any electrical accessory or apparatus.
- , **GAUGE** A notched plate used for measuring the diameter of wire, having a series of different-sized slots numbered according to standard wire sizes.
- , **LIVE** A conductor carrying a current and having voltage in it.
- , **NEUTRAL** The wire, in a circuit, which is grounded.
- , **RESISTANCE** A wire usually composed of nickel, chromium and iron which will glow a bright orange-red, without burning-up, as it transforms electrical energy into heat energy.

